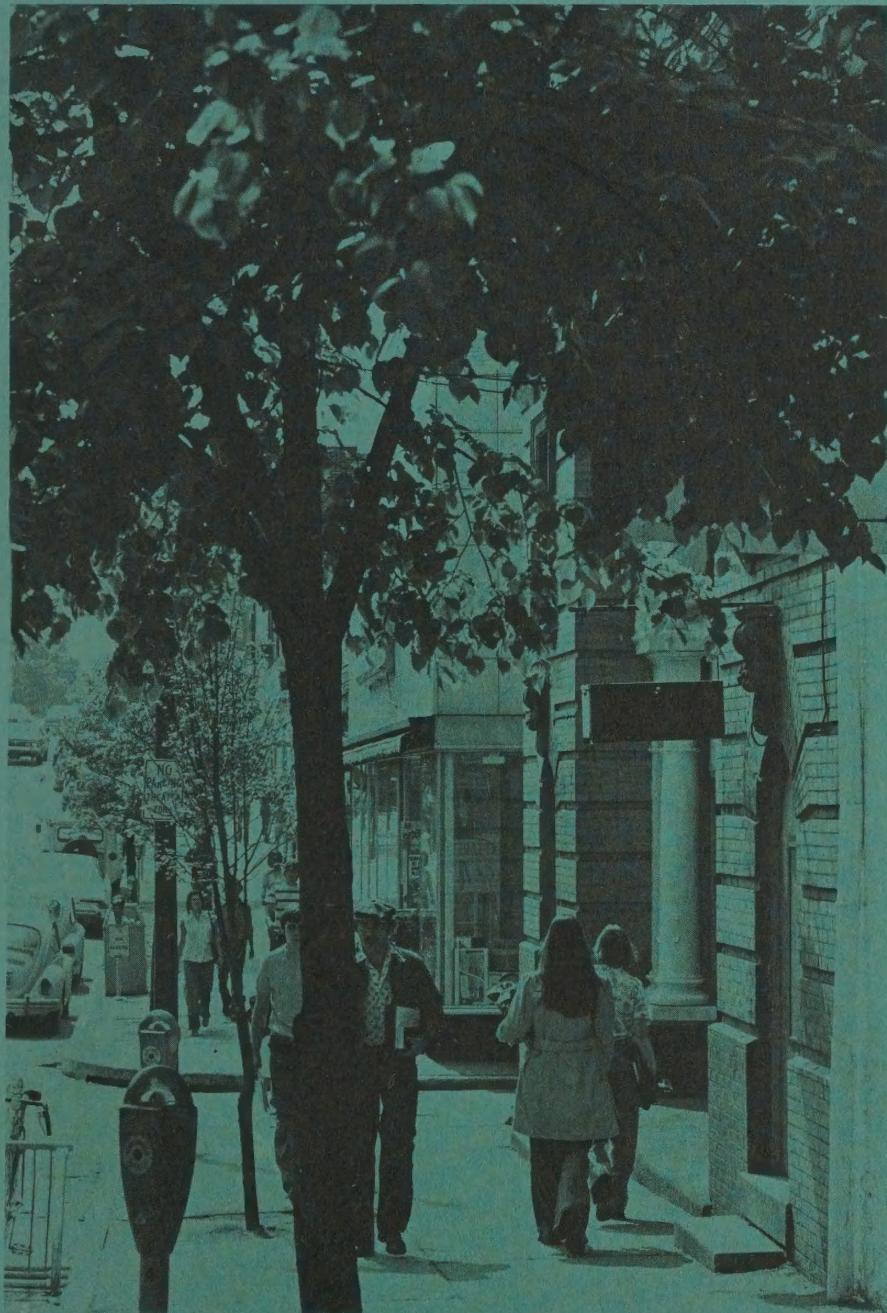


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Proceedings of the first
conference of the
Metropolitan Tree
Improvement
Alliance (METRIA)

Held at Lanham, Maryland
July 27, 1976

Proceedings 1978

PREFACE

The history and goals of the Metropolitan Tree Improvement Alliance have been well covered in an article in the Journal of Arboriculture 4(3): 62-66, 1978. Following the enthusiasm generated by the Symposium "Better Trees for Metropolitan Landscapes" that was held at the U.S. National Arboretum, November 4-6, 1975, METRIA held its first regular meeting in July, 1976. This is the Proceedings of that meeting. The delay in publishing these Proceedings is regretted by the Editor.

ACKNOWLEDGMENTS

The officers and members of METRIA are deeply indebted to their counterparts in the Northeastern Forest Tree Improvement Conference for allowing us to "tag along" in a joint-meeting format for our initial venture. All participants believed that this arrangement was of benefit to all parties.

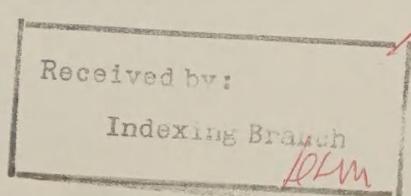
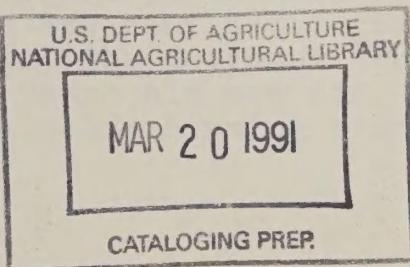
We also gratefully acknowledge the cooperation of the U.S. Forest Service, Northeastern Area, State & Private Forestry in providing support and publication of these Proceedings. "Urban Forestry" is a multi-faceted discipline requiring the cooperation and interest of all concerned with the future of "trees for people".

Frank S. Santamour, Jr.
Program Chairman and
Proceedings Editor

Cover Photo Credit: Pennsylvania State University, College of Agriculture

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TREES AND THEIR TYPICAL AGES AND GROWTH RATES ¹

by Thomas O. Perry, professor of tree physiology,
School of Forest Resources, North Carolina State
University, Raleigh, North Carolina 27607

INTRODUCTION

Our attention is captured by the unusual, the biggest, and the oldest of anything -- particularly trees. These are the individuals we photograph and write about. Thus, people including foresters are given to believe that trees live forever or at least a thousand years or more. Bristlecone pine and California redwoods do live for thousands of years but the life span of typical trees is much shorter. Several years ago, I was disappointed to note that fewer than three of the trees planted by Thomas Jefferson on the University of Virginia Campus and fewer than 10 of the trees he planted at Montecello are still alive and that there were no old trees (other than mulberries) at Williamsburg, Virginia.

How long do trees typically live and how rapidly do they grow? The following is a summary of data that may answer these questions.

DATA FROM FORESTS

Foresters tabulate the numbers of trees, their ages, and sizes for typical stands of many species. A review of these yield table data shows that Darwin's laws of geometric ratio of the increase and survival of the fittest hold. Competition in the young forest stand is intense with tens of thousands of seedlings per acre struggling to survive and dominate the main canopy. A typical hardwood forest will contain 25,000 or more stems per acre at year 1; 10,000 stems per acre at year 5; 1,500 stems per acre at year 20 and fewer than 200 stems per acre at year 100. Thus, less than one tree per hundred will live a hundred years. Visits to virgin forests like those in the Olympic National Park in Washington reveal a similar pattern of mortality. Only the rarest trees in the park may be 1900 years old. The typical maximum age of trees in this virgin forest is between 200 and 600 years old and these trees are confined to narrow bands along the streams. Most of the dominant trees of this forest are less than 250 years old and are, as with typical forests, the product of a self-thinning process that elim-

¹ Metro. Tree Impr. Alliance (METRIA) Proc. 1:1 - 12, 1978.

inated the vast majority of trees before they were 20 years old.

The situation is no different in the Joyce Kilmer Memorial Forest in the Southern Appalachians. The big trees there are confined to a few sheltered coves that occupy fewer than 100 of the 3,000 acres in the forest. New trees die there every year and there is more dead wood on the ground than in the main canopy. The highest number of growth rings I have ever counted among the many trees that have fallen across the trails is 320. The size an age of the trees decreases rapidly as one leaves the moist streams and sheltered coves and goes upslope to where fires and wind play an active role in addition to the normal processes of competition. The oldest trees on the ridgetops are much twisted and penetrated by rots that developed after historic fires. The average maximum age of trees on the ridge tops is between 100 and 220 years. Again the typical tree in this virgin forest dies before it has lived 20 years.

Rates of growth are highly variable in a crowded forest, and size bears little relationship to age. Trees growing without competition commonly attain diameters of 30 inches (76.2 cm.) or more by age 50 years while the same trees would attain diameters of only 3 inches (7.62 cm) when growing in a crowded forest. Rates of growth vary radically with the depth of the soil and availability of moisture and oxygen for a given site. The size a tree achieves at a given age is made even more unpredictable when these environmental variables are combined with the variable effects of crowding. Knowledge of the tremendous variation involved makes foresters fall into embarrassed silence when challenged with the question "how old is that tree?"

DATA FROM SINGLE TREES

Competition, fires, wind, insects, rot, and other agents, but particularly competition of other trees combine to make life harsh and short for most trees of the forest. Is the life expectancy of a tree in a park, protected by man, and free of competition any longer?

Some people chase after fire engines and ambulances. I chase after loggers and tree specialists, rights-of-way clearers, and construction firms to measure the stumps and count their growth rings. When possible, I like to arrive ahead of time and measure and record the condition of the trees before they are felled. Years of semilegible notes in sweaty pocket diaries reveal that undisturbed trees grown in the open areas of farm yards, house lots, parks, or cemeteries

achieve an average maximum age between 40 to 70 years before they succumb to some rot, insect, disease, ice storm, wrenching wind or lightning bolt. When spacing between trees is between 25 and 30 feet or more diameter growth is usually $\frac{3}{4}$ in. to 1 in. (2 to 3 cm.) or more per year for the first thirty years. Yard trees often attain diameters greater than 20 inches before they are thirty years old. Heights to the lowest limb of such trees are usually 12 to 20 ft. (3.66 to 6.10 meters) or less, and the total heights achieved by such trees are commonly between 50 to 70 ft. (15.24 to 21.34 meters). Such spreading "old homesite" trees are the "wolf" trees of most of our eastern forests and reflect a land use history of agriculture and land abandonment.

The rapid diameter growth of these early years continues as long as competition from surrounding trees is kept to a minimum and as long as construction workers and other diggers and burriers of tree roots are restrained. After the 20th to 30th year, diameter growth slows gradually but trees 70 to 80 years of age still commonly maintain annual diameter increments of $\frac{3}{8}$ in. (8mm) or more per year. A typical yard tree 40 to 70 years of age will have a diameter of 3 to 4 ft. (0.914 to 1.22 meters). Rapid growth rates and large tree sizes are not just confined to trees in southern latitudes or mild climates. The larger trees in the cemeteries of Maine and in the Royal Botanic Gardens of Edinburgh, Scotland are over 45 inches in diameter and 90 to 115 feet (114.3 cm. DBH and 27.4 to 35.0 m. height) tall even though they are less than 75 years old.

I have done my stump-sitting and ring-counting act from southern Florida to Northern Maine, from Los Angeles to the Olympic Peninsula of Washington, and from London to Inverness, Scotland. The results are amazingly homogenous. Wherever there is sufficient space for root growth, and water is in reasonable supply, and competition between trees is kept to a minimum, and man is reasonably restrained, the average maximum age of tree stumps is less than 70 years and the average diameter is between 3 and 4 ft. (0.914 to 1.22 meters). In urban situations, the vast majority of the stumps I examine posses fewer than 30 growth rings. Indeed, the majority of trees I examine in the puny planting holes (4 x 4 ft. and less 1.22 x 1.22 meters) that line our city streets are less than 15 years old.

The key take-home lessons from several hundred stump-sitting and ring-counting episodes are:

1. The average maximum age of open grown tree in the U.S. and the British Isles is much less than 40 to 70 years of age. Most city and forest trees are less than 20 years of age.

When water, roots space, and other resources are in good supply, tree growth is extremely rapid so that trees thirty years of age often attain diameters of 20 or more inches (50.8 cm.).

3. Growth in diameter and size is much slower in crowded forests than it is in yards.

4. Trees that are large are common, trees or stands of trees older than 120 to 150 years are indeed uncommon.

DATA FROM LANDSCAPE PLANTINGS

Random measurements of single trees only yield data on the average maximum age of trees. More precise data on average ages of single trees can be obtained by measuring the diameters of trees in multiple-tree plantings of known age and relating the frequency distribution of tree diameters to the diameter vs. age relationship of the largest and oldest trees present. Usually, I have been fortunate in locating a fresh stump so that the use of increment borers has not been required to obtain a diameter vs. age relationship. Figures 1 through 5 represent the results of two such studies. The horsechestnut planting at the Queen's palace at Hampton Court was planned by Sir Christopher Wrenn in 1699. Multiple rows of trees were set out extending some 4 miles from the formal entrance to the Palace. The spacing between the trees is 44 feet or 120 trees per mile. These colonnades of trees served as "rides" where the Queen and her court could ride horseback and where grand parades and receptions could be organized. The average diameter of the stump represented in figure 1 was actually 61 in. including the buttress roots but the effective diameter to where the growth rings were undistorted was 50.5 inches. The diameter-at-breast-height curve was estimated from measurements of 20 trees at both stump height and breast height. When the effects of root buttresses were discounted there appeared to be very little taper for the larger horsechestnut trees and the diameter at breast height of the tree represented by the stump was estimated to be 49 inches. As indicated in figure 2, a total of 84 trees were measured and one half of the trees or 42 were less than 16.5 inches DBH. Reference to the diameter vs. age curve based on measurements of the stump indicates that the age of one-half of the trees in the 276-year-old planting conceived by Sir Christopher Wrenn was less than 26 years. If one

assumes more optimistically that the half-life of a tree in this planting is 30 years and that mortality patterns are approximately described with a negative exponential function, one comes to the conclusion that the average tree in the Queen's ride has been replaced 9.5 times in the 276 years before my measurements were made in 1976. Further extension of these assumptions indicated that fewer than 0.1% of the trees in the original planting are still alive. Patient replanting by the Queen's gardener has yielded a long ride of trees which still maintains the solid visual impact intended by the architect. Only the deliberate observer who looks across the row is aware of the irregular size and survival of Her Majesty's horsechestnuts.

I have made similar observations of the rides planned by van Brugh for the Dutchess of Marlboro at Blenheim in 1719 and conclude that the elms in this planting had a half-life of less than 26 years before the depredations of the Dutch elm disease.

Sometimes it is possible to make estimates even when there are no stumps available and when use of increment borers would result in jail sentences. The 1920 planting of elm trees in front of the Lincoln Memorial in Washington, D. C. extended along the mall to the Capitol. A frequency distribution of diameters indicated that a maximum of 30% of the original trees were still alive in 1975. Again calculations based on an assumed negative exponential mortality pattern indicate that the average half-life of a tree in this planting is not more than 31 years.

Some trees are shorter-lived than others. The Japanese cherry trees in the planting that surrounds the Jefferson Memorial area and extends out Haines Point in Washington, D. C. are an example. Mr. Roland Jefferson of the National Arboretum kindly made a beautifully polished cross section from one of the Japanese cherry trees killed by hurricane Agnes in 1973. The first of the trees included in this beautiful planting were set out in 1912. A few of the original trees are still alive and present a picturesque array of twists, warbles, hollows, and rots. Even the newer replacement trees in this famous planting seem to be prone to one sort of plague or another. The ring counts and diameter measurements from the sample tree are summarized in figure 4, and a cumulative frequency distribution for 70 trees in the vicinity of the original planting site (figure 5) indicated that the average diameter of one-half of the trees was less than 5.2 inches (13 cm.). The data indicate that the average cherry tree in the vicinity of the Jefferson Memorial lives only 16.5 years.

The American landscape architect Olmsted planted many rides of trees. Many of the plantings like the one at

Franklin Park in Boston involved eln trees which have succumbed to the Dutch Elm Disease. An exception is the Mall planting in Central Park which was sprayed regularly until 1975. The half-life of this planting has been 35 ± 5 years. One of the more successful rides planned by Olmsted was for Cornelius Vanderbilt in 1897 on the Biltmore Estate near Asheville, N. C. Yellow poplar, (Liriodendron tulipifera L.) was the species selected and the trees have been provided with excellent care and growing space. After 89 years, only 16 of the original 52 trees in the planting have died and the calculated half-life of the planting is a remarkable 152 years.

Such longevity is an exception among the many rides and plantations that I have measured and it is more realistic to conclude that the half-life of a typical landscape planting is less than 30 years when conditions are favorable and less than 15 to 20 years along city streets. The intended design life of many buildings is 50 years or more. Architects will need more data like these for various species if the landscape plantings are to continue to enhance the beauty and comfort of our structures after beyond the first 20 to 30 years. A regular program of replacement should be planned; particularly in locations where the space for roots is small or where soil compaction from pedestrians and salt from roads and other insults will further shorten the normally short life of a tree.

CAPTIONS FOR ILLUSTRATIONS

Figure 1. Diameter vs. age relationship for a 184-year-old horsechestnut in the landscape planting at the Hampton Court Palace near London. This planting was conceived by Sir Christopher Wrenn and established in 1699. The trees in this famous planting have died and been replaced several times. Reference to Figure 2 indicates that one-half of the trees in this planting are less than 16.5 inches (41.9 cm.) DBH and estimations using the above graph indicate that one-half of the trees in this planting are replaced every 26 years.

Figure 2. Cumulative number of trees vs. diameter for a sample population of 84 horsechestnut trees in the planting at the Royal Palace at Hampton Court. One-half of the trees in this planting are less than 16.5 inches (41.9 cm.). See Figure 1.

Figure 3. Hypothetical percent survival vs. time for the horsechestnut planting at Hampton Court. See Figures 1 and 2. Assumed is a negative decay function in which one-half of the population dies every 30 years. The assumed 30-year half-life is more optimistic than the 26-year half-life indicated by Figures 1 and 2. Calculations based on these assumptions indicate the average tree in this planting has bee replaced 9.5 times since 1699 and that less than 0.1% of the trees from the original population are likely to be alive today.

Figure 4. Diameter vs. age relationship for a Japanese cherry tree planted near the Jefferson Memorial in 1912 and which was killed by hurricane Agnes in 1973. Reference to Figure 5 indicated that one-half the trees in this planting are less than 16 years of age.

Figure 5. Cumulative number of trees vs. diameter relationship for the 1912 planting of Japanese cherry trees in Washington, D. C. One half of the trees in this planting are less than 5.5 inches (13 cm.) in diameter.

FIGURE 1

HAMPTON COURT

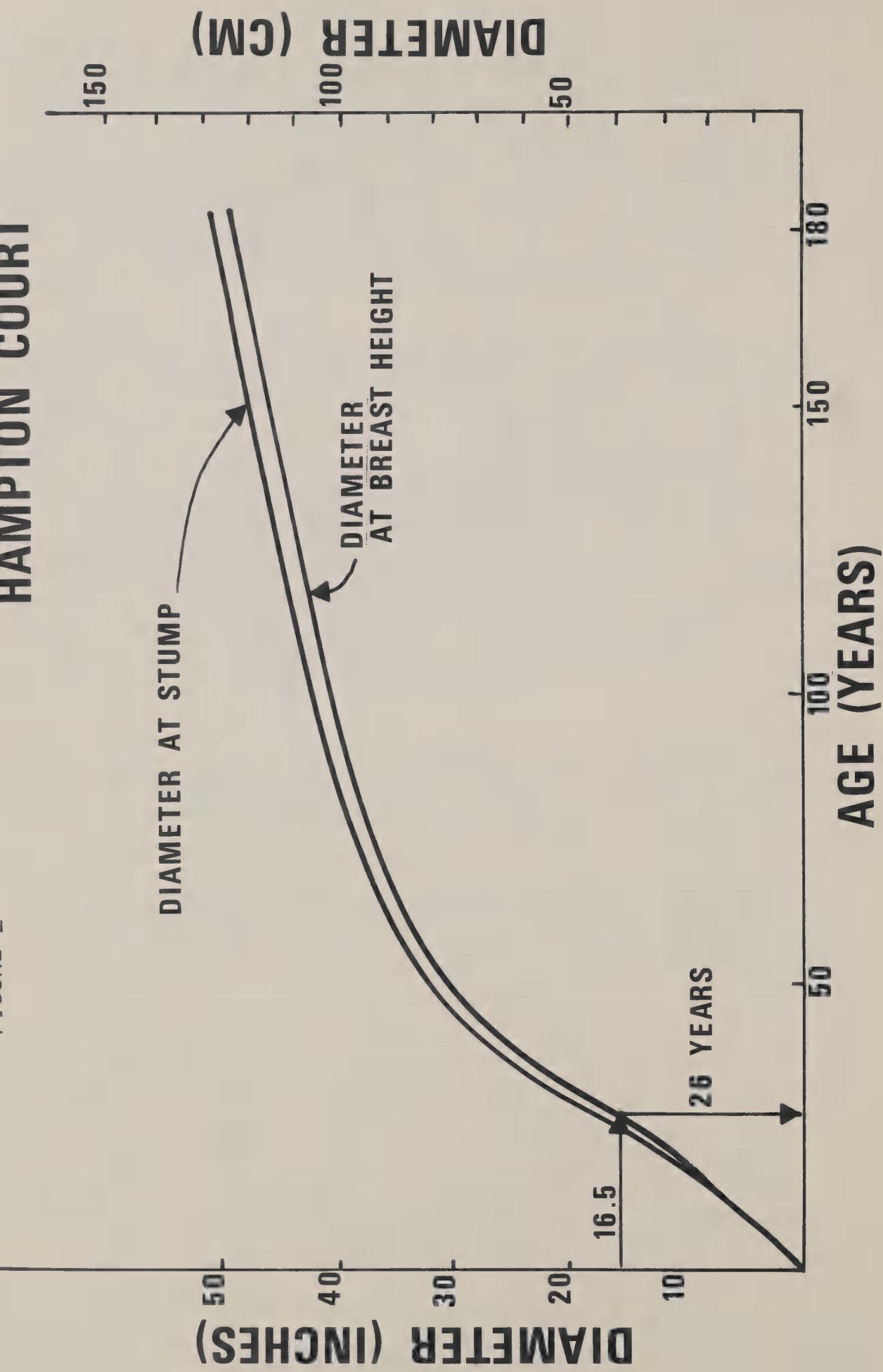


FIGURE 2

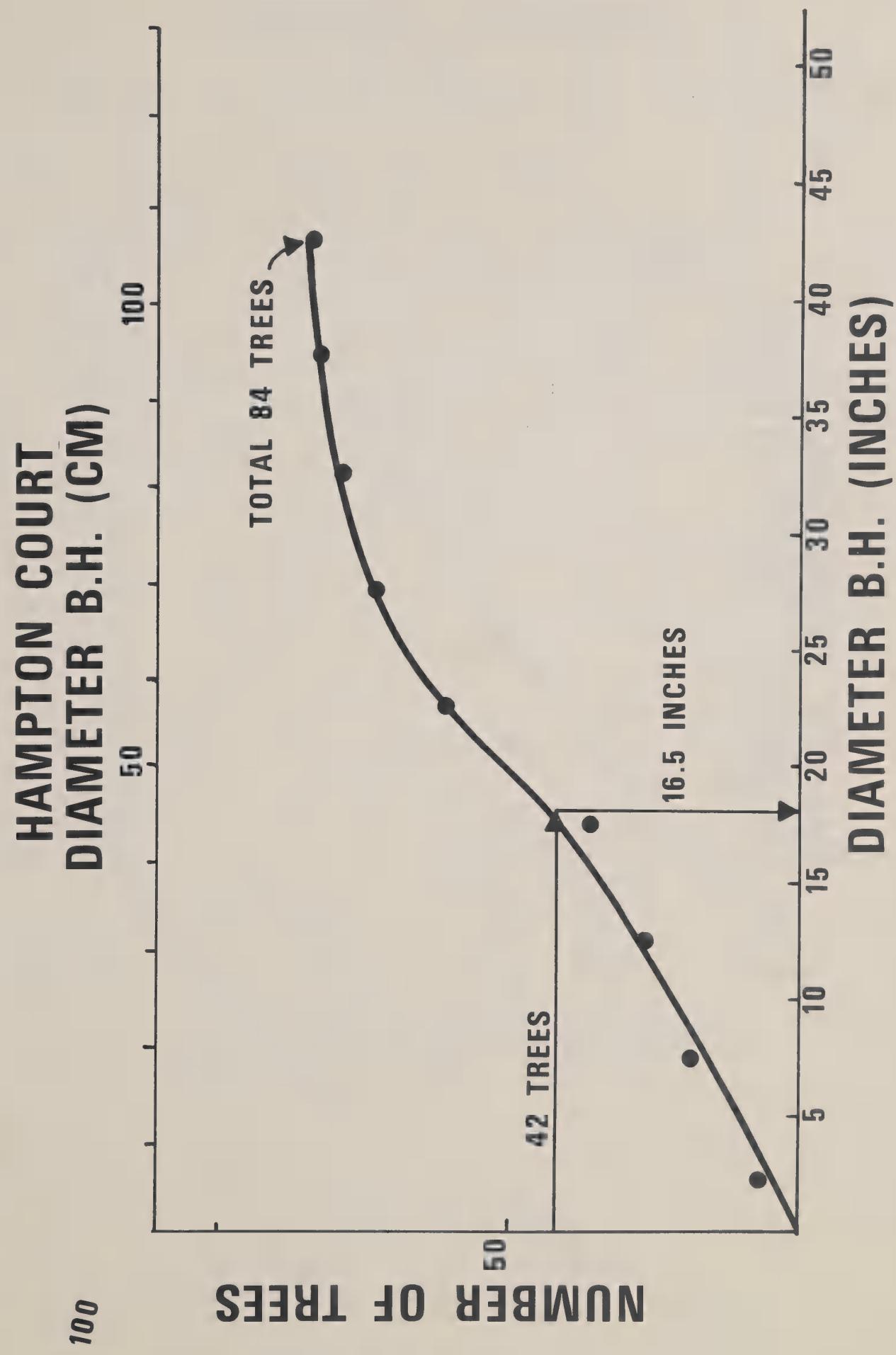


FIGURE 3

TIME VS. % SURVIVAL
FOR HAMPTON COURT TREES

PERCENT SURVIVAL

100 1/2 LIFE = 30 YEARS

50

10

50

100

150

200

YEARS OF AGE

FIGURE 4

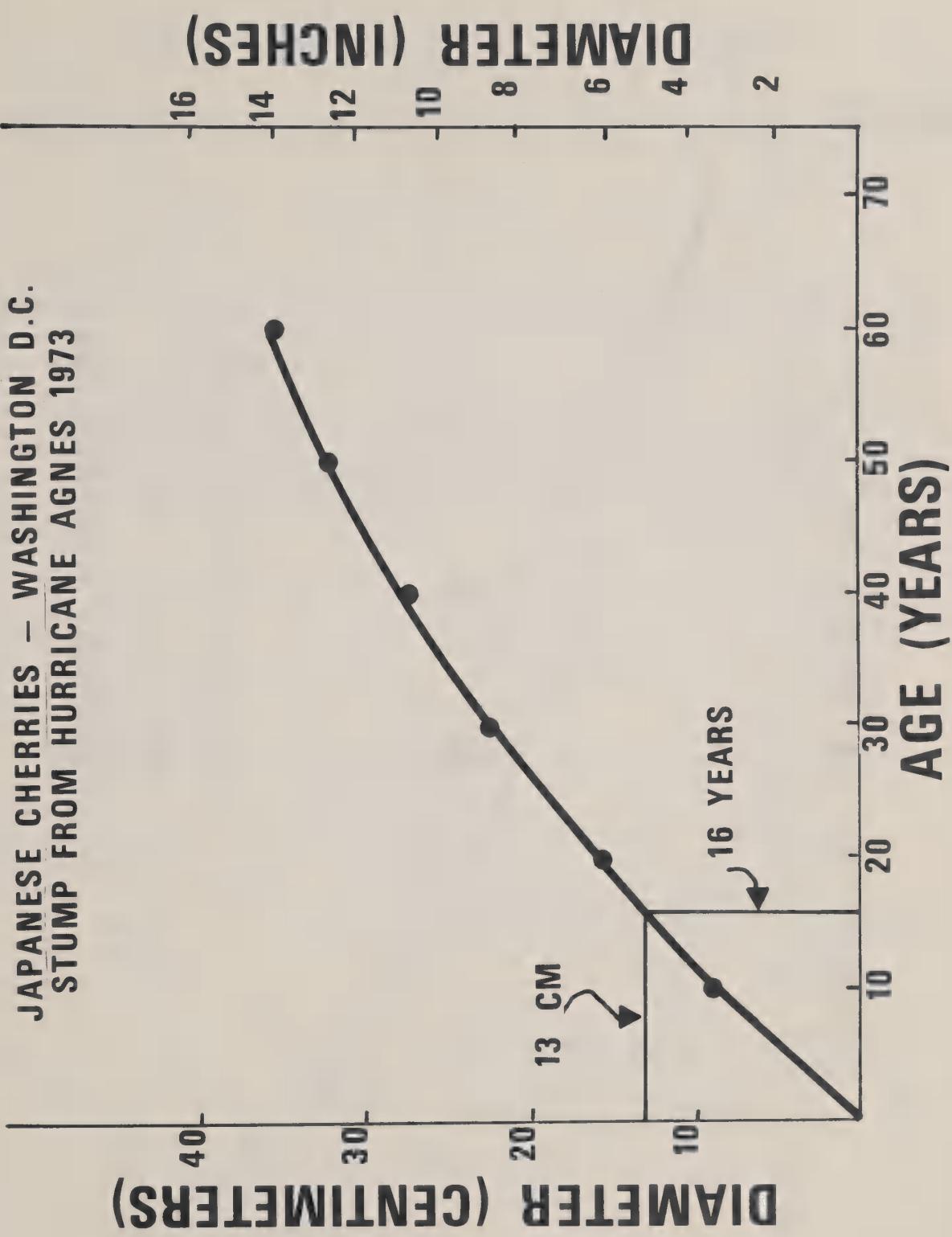
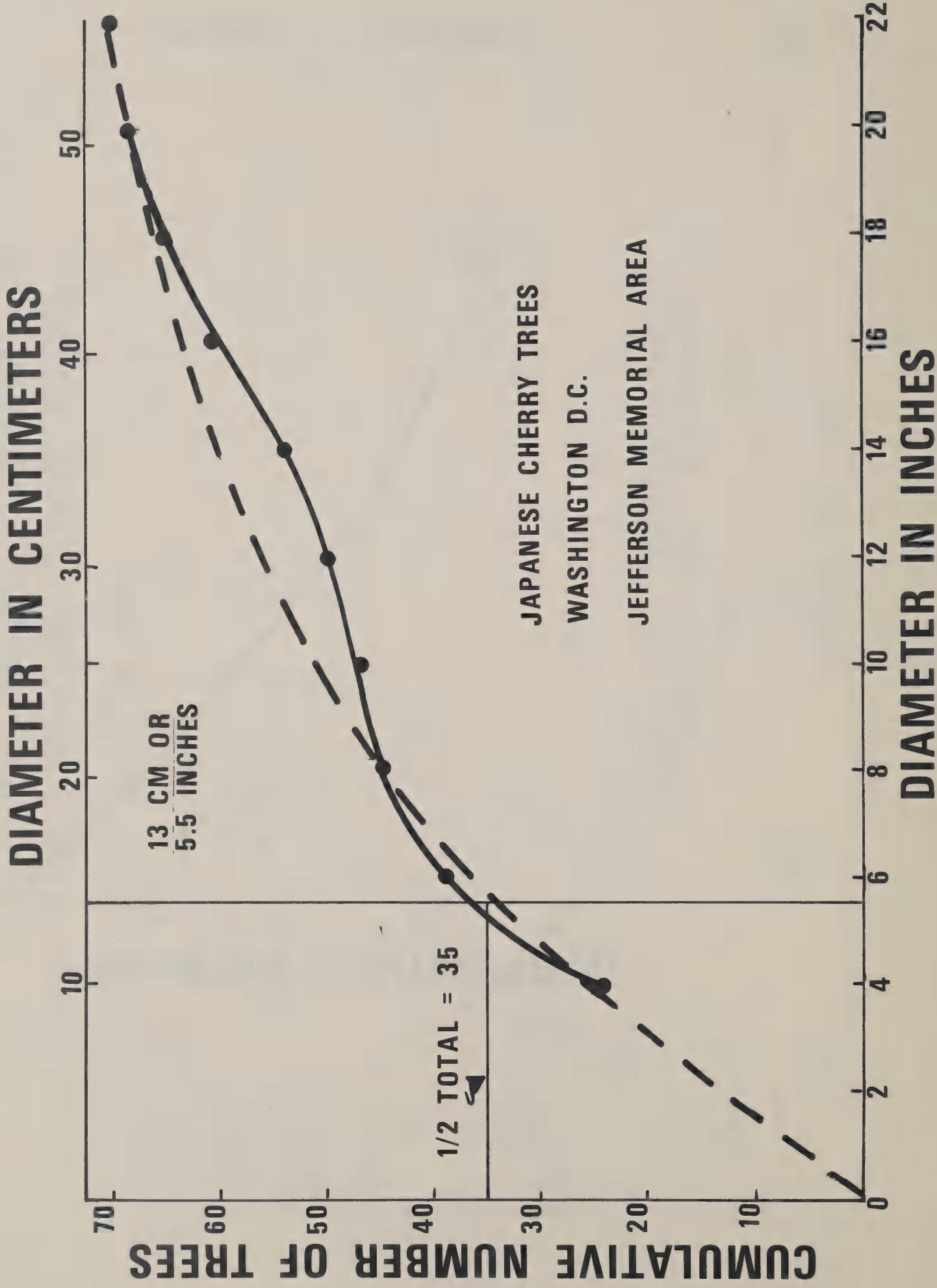


FIGURE 5



BIO-ENGINEERING FOR THE URBAN ECOSYSTEM¹

by Ruth S. Foster, landscape consultant and author, former assistant tree warden, City of Boston, Massachusetts

INTRODUCTION

The commonest cause of tree death in the city is the engineer. Environmental pockets are made by his design or his lack of it. Often they are not suitable for any plant life short of hardy weeds.

It is necessary to rethink the conventional platitudes of city tree planting. What works in the forest can not be expected to perform satisfactorily in the city. It is not enough to dig a hole and stuff in a tree, particularly in concrete.

Of the parameters of biomass production that affect survival and performance in the urbanizing landscape, water stress is the most serious problem. It supercedes good soil, special clones, insect and disease control and pollution.

Statistically, however, the most significant problem, is continuing construction and careless engineering. New roads, signs, lights, pipes, bus stops, cables, sewers, curbs, sidewalks, assault the root structure and growing medium (Fig. 1). More trees were lost in the Boston Common Park to construction in 1975 than in 3 years of epidemic Dutch elm disease. New paths carelessly planned, unnecessary sewers, and \$350,000 of new granite curbing were to blame.

Far more important than the actual physical damage to roots and trunks, is the permanent damage done in changing the microenvironment. When runoff water is piped into the sewer, the water table which nurtured the tree disappears. Water stress follows, with fungal infections close behind. Equally important, soil over the roots is compacted by machinery, and frequently covered with concrete or blacktop. Air exchange to the roots ceases.

In a survey of tree survival, it was found that most curbside trees on sidewalks do not live anywhere near a normal life span. The commonest cause of death is drought. The commonest injury auto damage. Statistically, vandalism is not a primary problem. Construction is a paramount problem.

¹ Metro. Tree Impr. Alliance (METRIA) Proc. 1:13-17, 1978.

Bio-engineering is simply applying the parameters of biomass production in an organized fashion to plan the pockets where plant material must survive. It is more cost-effective than planting material in uninhabitable micro-environments, doomed to failure.

ENGINEERING AND TREE GROWTH

The city is a created landscape. It is not the forest. The rules and priorities of conventional silviculture do not always apply in an urban setting.

There is no humus, no seedlings to renew the urban forest and little soil, except in parks. The air is hot and dry. Excessive heat radiates from buildings, winter and summer. Searing winds are generated by the "canyon effect" of tall buildings. Even the climate is different, changed by the well-known "heat-island effect" of the city. Changes in rainfall patterns and air pollution inversions affect growth rates.

To further complicate this concrete landscape, microenvironments exist within the larger framework. The north sides of buildings may never have any sunlight, while south facing pockets will suffer the variations of temperature common to deserts. While it is true that there is a tree for each environmental pocket, it may be only a cactus. It is better to engineer planned environments that will support trees and plants. Educating engineers, though undeniably difficult in the field, is essential.

BIO-ENGINEERING FOR WATER STRESS

The parameters of biomass production are well-known. However, the relative importance of each is different in the man-made city. Water stress, the primary problem in cities, can be alleviated. Drainpipes should go through perforated pipes under tree pits. The water would be used by the trees. The overflow would still end up in the storm sewer, or better, percolate into the soil to recharge the underground aquifer. The same thinking can design irrigation with uncontaminated waste water. Storm sewers should be planned for re-use of light rainfalls, with overflow sewers for heavy rain only. Sewers in parks are unnecessary. They are destructive both in construction and in damage to the water table. Bringing the blind enthusiasm of engineering endeavor into parks destroys the few natural green oases that exist in the concrete city-scape.

The City of Boston just spent \$100,000 putting new sewers in its downtown park, to remove water from the paths. The needed water drains into the bay. During a drought in June, a crisis operation had to bring water with trucks and hoses.

POLLUTION DAMAGE

With the current sensitivity to the health hazards of pollution, it is popular to apply the same thinking to trees. Growth is compromised by air borne pollutants. Growth rates and disease susceptibility are affected. Leaf damage is seen. The most troublesome are auto fumes and particulate ash. Research has been sporadic about effects in vivo. Probably the total effect on survival rates is highly over-rated, when compared, statistically, to damage done by water stress and construction, as well as mechanical damage. Salt is the exception, damage from which is widespread. It can be avoided if planting pits are not adjacent to areas of pedestrian and auto use, and by the use of salt-resistant trees.

MECHANICAL ABUSE BY PEOPLE

Auto damage and vandalism are the two serious causes of mechanical damage to city trees. They are too frequent to be dismissed lightly. Autos cause the disproportionate share. Few large trees bear no scars of damage. Young trees are seriously compromised because of their tender bark. Auto damage may occur on 81% of sidewalk trees in a business area. 30-50% is not uncommon elsewhere. The closer the tree to the curb, the higher the incidence. Trees set back far enough to avoid car doors and parking, are less affected. Barriers help. Tree stakes do not. Often they are damaged by cars to the point where they actually are hanging on, not holding up, the trees (Fig. 2). Much of the fungus decay (that eventually claims the trees' lives) starts as auto wounds.

Vandalism is highly over-rated except in areas of high child use, such as playgrounds; or near pubs and bars. On the streets, approximately 10% are gouged or cut. About 15% have broken branches, although many of these are from being hit by trucks. Wrapping helps protect them when first planted. Torn lower branches are helped by simply having the canopy of branches begin above six feet. Nurseries should train shade trees when young to a high canopy, especially varieties like linden, Callery pears and flowering species.

An interesting observation was that trees with flowers planted around their bases were rarely vandalized.

STAKING

An observation that flies in the face of all conventional planting data was borne out in a statistical analysis. Staking in the city is a losing battle. 80% of the stakes end up damaging the trees (Fig. 3). Except in windy areas, stakes are not really necessary to help a tree get established. Survival rates are not markedly different between staked and unstaked trees.

MAINTENANCE

Another reality of the city is the fact of poor maintenance. Trees should be planted, and expected to survive with no follow-up care. It is one of the inescapable realities of the urban ecosystem. Correct engineering of the microenvironment can produce a planting pocket that is self-sustaining.

THE RESULT

The result of city environmental parameters is that trees adopt the growth habit of desert plants. They grow slowly, mature over-early, have small leaves and huge crops of seeds. They conserve their energy to remain alive, rather than becoming the expected giants of the woodland.

SURVIVAL RATES

Longevity is not what is genetically expected. In surveys done on street trees in Boston, only 15% were over 12 inches in diameter. Extensive planting was done at the turn of the century, but few large trees remain. On Beacon Street, in 1911, about 350 lindens were planted. Sixty years later they should be in their prime, yet only 81 have survived, only 55 of these in healthy condition.

Survival of young trees is poor too. On another street, 116 honeylocust, plane and maple were planted 6 years ago. Today 31% are healthy, 33% in poor condition, and 36% dying, dead or gone. One year survival rates depend largely on contractor competence, and regular water. In one year, in Boston, 4 contractors had loss rates of 35%, 12%, 9% and 2% respectively. Good planting techniques and special acclimatizing make the difference.

The survival statistics point up one more parameter...a political one. City bids go to the low bidder. It is difficult to weed out poor performers. The realities of city politics, bidding procedures, entrenched hierarchies and neighborhood neglect and abuse must be reckoned with.

THE FOURTH DIMENSION-TIME

The landscape is a 4-dimensional discipline. Trees grow. Their sizes change. Too often, engineers and architects overlook this obvious fact. Even city foresters do...and plant maples under electric wires.

With proper bio-engineering, attention to growth parameters will pre-tailor trees to grow the right size in the right place, with little additional care. In preparing a matrix, factors to include in the urban scale would be; sun, shade, soil, wind, water, cars, insects, diseases, people, animals, pollution, macro-and micro-environment, construction, politics, as well as aesthetic qualities and uses.

CONCLUSIONS

Bio-engineering means planning for optimal survival and health, environments to support temperate trees and shrubs. Construction and tree planting need more coordination. Protection from autos, salt and drought can be designed in. Monocultures must be avoided, so that no one disease can decimate a whole street or area, as Dutch elm disease has in places.

Since trees don't live very long in concrete anyway, fast growing varieties can be used. Staking should be eliminated, except in special circumstances. Water has to be provided for, either as runoff directed into the pit or simple irrigation with runoff from buildings.

Most interestingly, studies suggest that sidewalks are not the best place for trees. They should be planted inside the pavement, rather than at the curb side. Ideally they should be planted in plantations, squares and parks. They survive better and suffer less vandalism. The ground should be unpaved beneath them.

In the urbanizing landscape, the parameters of tree growth have to be viewed as part of the total environment. Most urban forestation starts at the wrong end. If plant material is to survive--and possibly thrive--bio-engineering and total planning procedures have to be applied early-on.

THE HOLMDEL ARBORETUM:
SERVING THE CITIES OF
NEW JERSEY 1, 2.

by David C. Shaw, Superintendent, Shade Tree Commission of Monmouth County, New Jersey

1. The Holmdel Arboretum story begins in the spring of 1963, when the members of the Monmouth County Shade Tree Commission conceived the idea that an arboretum of ornamental trees and shrubs and a display of conifers and broad-leaved evergreens would be of great interest and value to homeowners in our country.

2. The County had just acquired park land in Holmdel that would be well suited for such a project. Permission was requested by the County Shade Tree Commission from the County Department of Parks and Recreation Commission to have an area set aside in this park for an arboretum--and it was granted.

3. Twenty-two acres of partially wooded rolling countryside which bends into a 4-acre lake was selected for the project.

4. Mr. Robert B. Clark, then of Rutgers University, was asked by the Shade Tree Commission for assistance in planning the Arboretum. Mr. Clark inspected the proposed site and outlined the basic plan which is still being followed today with only slight alterations.

5. Now that the Shade Tree Commission had a plan to work from, the nurserymen of Monmouth County were invited to a dinner meeting to discuss our proposal for the development of an Arboretum. We asked them for recommendations for the initial planting. The nurserymen were enthusiastic about our proposed project and eager and willing to supply, by donation, plant material for the Arboretum and to give helpful advice when needed.

¹. Metro. Tree Impr. Alliance (METRIA) Proc. 1:18-21, 1978.

². Editor's note: This presentation consisted of a series of slides depicting the growth and development of the Holmdel Arboretum.

6. By the end of the fall, 1963 planting season, many flowering cherries and crabapples were donated. Our crews in most cases dug and planted the trees in the Arboretum.

7. American hollies were highly recommended. 'Old Heavy Berry' and 'St. Mary' were the first cultivars to be planted.

8. The next few years were spent planting cultivars of crabapples, plums, almonds, and cherries. Along the lake, a 600-foot expanse of weeping cherries (Prunus subhirtella pendula (Maxim.), Tanaka and Prunus 'Beni-higan' were planted to take advantage of reflections from the lake. This planting was dedicated to the memory of Mr. William Duryee, the Commission's first chairman.

9. Groupings of pines were planted as a background for the Prunus collection. These pines included Japanese black, Japanese red, Austrian, Himalayan white, Scots, and eastern white pines.

10. We now have a collection of more than 30 varieties and cultivars of Prunus.

11. To travel to the crabapple collection, we proceed over a small rustic bridge. During the spring, thousands of daffodils provide a carpet of yellow throughout the ravine that divides the Arboretum into two distinct sections.

12. Beyond the bridge and to the rear of the ravine, a rhododendron and azalea garden has been started. Mr. Wells, from Wells Nurseries is assisting us with this project and has already donated hundreds of plants for the gardens.

13. About 30 varieties and cultivars are now included in the crabapple collection, and we expect to have 50 extra when it is completely planted.

14. A collection of flowering shrubs with attractive berries has been planted for autumn interest--and to attract birds.

15. The holly collection today includes numerous cultivars of American and Japanese hollies.

16. Franklinia is also displayed in the holly collection. This tree blooms from August until the first frost. It is a native American tree that has been extinct in the wild for more than 100 years.

17. To the left of the holly collection, we see the area where specimen landscape trees are planted; among which are the Amur cork tree, 'Bradford' pear, Zelkova, and many others. More trees will be added to this section next spring.

18. We have a fine collection of hawthorns, and many are recommended for street planting.

19. We now see the River's beech (Fagus sylvatica 'Riversii') that was planted in memory of Laura Prout, the Commission's second chairperson.

20. The next area is the site for the Jane Kluis Memorial Dwarf Conifer Garden. This garden has been donated by nurseryman Rudy Kluis, in memory of his wife.

21. This collection consists mainly of dwarf conifers, with some larger evergreens and deciduous plants for contrast. The garden has just been started and will take several years to complete.

22. A rare dwarf golden oak from Holland is one of the many rare trees in this garden.

23. A collection of true cedars, donated in memory of David Rossheim of Holmdel by his friends and neighbors, is well established. This collection includes Atlas blue cedar, cedar of Lebanon, and deodar cedar. We have recently added a Kashmir cedar, a Cedrus brevifolia, and an upright Atlas cedar-- all donated by Mr. Kluis.

24. Another part of the Arboretum is the Handleman Garden. This garden has about 60 species, varieties, and cultivars. Mr. Handleman had previously donated plants to the Arboretum and was pleased with our efforts.

25. Mrs. Minna R. Handleman knew how much her husband loved his plant material around his home, so she donated it to the Arboretum. This collection simulates the exact planting design around their home in Colt's Neck. A large sourwood in this garden was planted in memory of William Porter by his sons Bill and Tom.

26. Below the Handleman Garden is a collection of witch hazels, cotoneasters, fringe-trees, sourwoods, and a large collection of junipers.

27. A magnolia and dogwood collection is also established on one side of the Handleman Garden. Several cultivars of these genera are being used for street tree planting by Shade Tree Commissions.

28. An English holly collection is planned for the rear of the Handleman Garden. Early plantings have been more successful than we expected. Osmanthus is also included in this collection.

29. Ground covers of juniper cultivars have already been established. These are used in island plantings along roads and highways. They seem to tolerate winter salting for snow removal better than other ground covers we have used.

30. We also have a nursery where we raise young plants and grow them until they are large enough for the Arboretum and our own street tree planting operation. This saves us considerable money and we are also able to raise materials not available in the commercial nurseries.

31. The Arboretum was dedicated in 1965 to the nurserymen of Monmouth County, who so willingly donated more than 500 species, varieties, and cultivars, and to Mr. William Duryee, the first chairman of the Monmouth County Shade Tree Commission.

32. The nurserymen's plaque includes the names of Wells Nursery, Princeton Nursery, Monmouth Gardens, Alvarez Nursery, Bobbink Nursery, Manalapan Nursery, Kluis Nursery, Laurel Hill Nursery, F & F Nursery, Moreau Plant #1, Holly Acres, Lovetts, Bucklin Farm Nursery, Turner Bros., Halka Nursery, Moreau Landscape Service, George Ehrle Nursery, and Bulk's Nursery.

33. The latest large specimen tree we transplanted to the Arboretum was a dwarf weeping Japanese red cutleaf maple. The tree was over 100 years old and had been in its previous location for 80 years.

34. The tree and ball weighed over 6 tons, and we used three layers of burlap and a mile of twine. Chet Halka of Halka Bros. donated his services to insure that the tree lived during transplanting.

35. The Holmdel Arboretum is open all year from 8:00 a.m. to dusk and is free to the public. It is located in Holmdel Park, Longstreet Road, Holmdel, New Jersey. Information can be obtained from the offices of the Monmouth County Shade Tree Commission. The Arboretum is just one of the many services rendered by this Commission.

THE ROLE OF STATE & PRIVATE FORESTRY IN IMPROVING FOREST TREES FOR URBAN USE¹

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INTRODUCTION

Many of you probably wonder what a U. S. Forest Service forester is doing at a meeting on improvement of trees to be planted in metropolitan areas. You may have a traditional picture of the forester as a stalwart ally of Smokey Bear--fighting fires, planting trees, managing campgrounds and wilderness, and finding people lost in the great forests of the mountainous West.

A more recent misconception depicts us foresters as destructively clearcutting great tracts of virgin forests in cooperation with big corporate timber interests. How and what are we doing in urban forestry? Do we really have a legitimate role in the very specialized job of developing better trees for street and park planting.

WHERE S&PF FITS IN

Many, if not all of you, may also be wondering exactly what is the role of State and Private Forestry. Incidentally, this is a comment that is often raised by foresters, even by those within the Forest Service. So first, I would like to tell you a little about the organization of the U. S. Forest Service and then get into the topic of State and Private Forestry and metropolitan tree improvement.

The National Forest System manages 165 million acres of National Forests in 42 states. These federally-owned acres are used for timber production, camping, hiking, hunting, fishing, watershed protection, esthetic enjoyment, range production, and wilderness recreation. Much of this acreage was reserved from the public domain lands of the West, but considerable acreage east of the Mississippi was purchased from private ownership.

The Research Branch--and several researchers are on the program this afternoon and in the audience--is devoted to

¹ Metro. Tree Impr. Alliance (METRIA) Proc. 1:22-27, 1978.

developing better methods of growing, protecting, and managing all the resources of forest and range land. Their work includes protection from fire, insects, and disease; culture, growth and harvesting of timber; tree genetics; wildlife-habitat improvement; watershed management; use of forest land for recreation; range management; forest survey; forest products; forest engineering; and forest economics. Relatively recent additions to the research program include study of the urban and suburban environment, with emphasis on vegetation, wildlife, and recreation.

State and Private Forestry--S&PF for short--the smallest branch, has as its mission the administration of the various federal programs that provide financial and technical assistance to the states to further their forestry programs. These programs stimulate better forestry through federal matching funds and technical assistance. Much of the state effort helps the private landowner manage his woods to produce the benefits that he desires and society needs. About 60 percent of the nation's timberland is owned by the small non-industrial landowner; improved management of this land can make an important contribution to the nation's welfare.

A great deal of this work has been directed into the traditional timber-oriented activities: tree planting, timber-stand improvement, timber sales, fire prevention and control, and pest management, because most landowners seek the state service forester's advice on timber problems. The landowner wants to know: How do I manage my timber? Where can I sell it? What volume and value do I have?

TECHNICAL ASSISTANCE

But now we see a change toward more emphasis on non-timber uses. This fiscal year, Congress has appropriated half a million dollars to be used for Multiple Use Technical Assistance. This money will enable us and the states to provide expertise in nontimber disciplines such as wildlife biology, landscape architecture, watershed, and range, to provide wider options to the landowner in managing his forest and range lands.

An important part of S&PF's effort is technical assistance, really educational activities to increase the professional skills of the state-employed forester, both the service forester dealing with small private landowners and the manager of the many acres of state-owned forests. In the 20-state area served from our Pennsylvania office, nearly 13 million acres are in state ownership. These states contain half of our nation's population, so their state forests are under heavy pressure to provide recreational opportunities as well as forest products.

These S&PF activities are aimed primarily at the rural forest resource, not the urban tree or suburban green space. How does S&PF become involved with urban and community forestry? Although the Forest Service has long recognized the importance of the urban and community forest, it was not until 1972 that the Cooperative Forest Management Act of 1950 was amended to provide technical and financial assistance to the states for the "protection, improvement, and establishment of trees and shrubs in urban areas, communities, and open spaces". This is our statutory basis for engaging in urban forestry cooperation with the states. An additional 5 million dollars was authorized by this amendment, but the money has yet to be appropriated. We do have reason to believe that funds will be appropriated for urban forestry in the near future.

The intent of this authorizing legislation is that the present level of appropriations will continue to support existing programs. The National Association of State Foresters gave its sanction to this. Thus urban forestry funds will not be available until Congress appropriates funds specifically for urban forestry. Without such funding, S&PF cannot undertake the highly active role in urban forestry that it wishes to.

IMPROVING URBAN TREES

So much for our statutory responsibilities in urban forestry. How does State and Private Forestry work for improvement of metropolitan trees? In fact, you may be wondering if S&PF has any role in development of improved trees for the urban forest, since we cannot engage directly in research.

But S&PF nevertheless does have a role in the improvement of urban trees. Through our relationship with 20 states and their foresters working part-time or full-time in urban and community forestry projects, we can develop a network of observers who are in daily contact with urban tree problems and opportunities throughout the Northeast and Midwest. These foresters provide a mechanism for observing difficulties that are encountered with existing varieties, cultivars, and species under a wide range of climatic conditions, from the cold climates of Maine and Minnesota to the relatively warm and humid Eastern Shore of Maryland and west to the hot and frequently droughty Missouri.

In our contacts and travels throughout this territory, we in S&PF can gather information on many facets of urban tree use and care. Many of you have restriction on your

travel and are often confined by state boundaries; but, in the administration of other funded federal programs, I can directly observe and discuss urban tree problems in 20 states. I should not restrict this gathering of information only to our 20-state territory. In the South, my counterpart, Bob Nobles, has the same capability in 13 states and has been developing his contacts for several years longer than I. In the West, the Forest Service also maintains State and Private people, so that the entire country can be covered by this type of information network.

We also have a more formal system of gathering information in the Northeastern Area, operated in conjunction with the Northeastern and North Central Forest Experiment Stations. This is the "Research Needs Program", into which the state foresters and their staffs are encouraged to feed problems that require research solutions. These needs are sent to the appropriate research project for comment and consideration. The Northeastern Forest Experiment Station maintains three projects in urban forestry and coordinates and funds the activities of the Pinchot Institute for Environmental Forestry Research. Although most of the research-need requests have been concerned with silvicultural, management, and protection problems, we have had a number of inquiries about urban trees.

We can help the urban tree geneticist through our research-implementation activities. Research implementation is an educational activity through which we bring to potential users the latest research information and explain how it can be put into practice. This is done through publications, workshops, and show-me trips. Initially, the researchers who have developed the new information frequently participate actively in research implementation; later as we become more familiar with the information, the researcher goes back to his studies and we continue the educational work.

Our efforts are limited to the professionals employed by the states, who in turn will influence a larger number of individuals concerned with urban trees. Thus we have an established mechanism for bringing the results of your work to potential users. If great masses of urban and suburban residents and landowners are to be reached, this is done through the Extension Service and the state-employed urban foresters who frequently hold meetings for interested groups of urban people. The mass-medial communications specialists of the Forest Service also help with television, radio, and press outlets.

Tree improvement is a lengthy process, except perhaps for clonal propagation of some lucky sport that has highly desirable features. Until the improved tree is outplanted in the community, the work of the breeder does not come to fruition. We can help in this final step.

COMMUNICATION AND EDUCATION

A continuing theme in the Urban Forestry Working Group of the Society of American Foresters, the Urban Forestry Committee of the International Society of Arborists, in urban forestry workshops such as this, and in all meetings of urban foresters, is the need for better communication among urban foresters. Urban forestry is a new and loosely defined field; it does not have the formal lines of communications that are found in the older professions; it is difficult for urban foresters to become acquainted with one another and learn of their activities. S&PF can promote better communications.

An important S&PF activity is helping to organize, sponsor, and encourage meetings such as this. We have agreed to publish the proceedings of this METRIA meeting. This publication should help establish METRIA as an important forum for urban tree researchers. Next year, we will cosponsor with the host State, Ohio, an urban forestry workshop for our 20 states. The program and location has not yet been selected, but Wooster is favored because of extensive outplanting trials of shade-tree selections on the grounds of the Ohio Agricultural Research and development Center.

Last year a workshop for 13 southern states was jointly sponsored by Florida and S&PF, through Bob Nobles in Atlanta; and the proceedings have been published. A second one is planned within 6 months. Tree breeding and selection continues to be a topic at these meetings. Such meetings expand knowledge of research for the practitioner and should help in getting improved trees into commercial channels for propagation and use.

I believe S&PF's role in urban tree improvement can be summed up in two words: COMMUNICATION AND EDUCATION. We can speed communication among people involved in tree improvement, not only the working geneticist, but also those responsible for propagating, outplanting, and caring for improved trees. We encourage this communication through urban forestry workshops and symposiums, publications describing latest usable research results, and travels and contacts in our 20-state service areas.

There is still a great gap in our urban forestry communications. State and Private Forestry seeks to help to close that gap.

In education we provide technical assistance to the staffs of state foresters in urban forestry in its broadest sense. Although we are presently limited by the absence of specific funding for urban forestry activities, we can sponsor forestry workshops and training sessions in which you are invited to report your progress. The urban tree geneticist can receive feedback from practicing urban foresters at these sessions.

Our established policy is to encourage better care and use of urban trees. We are optimistic that we will shortly have federal appropriations for urban forestry. I predict that expanded programs at the state level will open great opportunities for outplanting of all those better varieties that will help us to expand urban forests for the future.

STRUCTURE OF URBAN STREET TREE POPULATIONS
AND
SAMPLING DESIGNS FOR ESTIMATING THEIR PARAMETERS

by P. Mohai, L. Smith, F. Valentine, W. Stitelser,
T. Elias, and R. Westfall¹

ABSTRACT.--Census data for 7372 street trees in Poughkeepsie, New York have been analyzed to elucidate population structure, species and cultivar composition and their distribution. Only fourteen of the 113 species and cultivars are present in sufficient numbers (29 or more) to permit inferences on dispersion and density. For the eleven most common, more than half occur in clusters. The remaining three species exhibit a widely dispersed pattern, mostly as single specimens. True population variances for stem height and diameter of the five most common species among the older tree populations were used for comparisons with estimates of variance obtained in computer simulations of various survey sampling methods with these data. Cluster sampling procedures provide an unbiased estimate of variance. Greater precision in the estimates results when a larger number of clusters, i.e. randomly selected streets, are surveyed and when the sampling interval between trees is larger. Fifty to 100 clusters appear to be adequate in number. The sampling interval may vary among species, with its size dependent upon species' incidence, total population size and the desired sample population size. Sample population sizes of 100 and even smaller provided reliable estimates of the true variances for four of the species. Differences obtained for the fifth, red maple, are attributed to the concentration of most of the younger trees along one street. Hence variance estimates would be markedly affected by either the presence or absence of this street in the random sample. A larger sample population size and a greater number of clusters may be advisable for large urban centers with greater environmental

¹Graduate students and faculty of the Suny College of Environmental Science and Forestry, Syracuse, New York, except for Dr. Elias, Assistant Director, Cary Arboretum of the New York Botanical Garden, Millbrook, New York. Portions of this study fulfilled part of the requirements for the M. S. degree of the senior author.

variability than occurs in Poughkeepsie, a relatively small city in the lower Hudson River valley. The proposed cluster sampling method, however, should be applicable to cities of any size with any species composition as long as the trees of each species or cultivar occur predominantly in clusters. Metro. Tree Impr. Alliance (METRIA) Proc. 1:28-43, 1978.

INTRODUCTION

Since the near total elimination of the American elm (Ulmus americana L.) due to Dutch elm disease in Syracuse, New York in the past 15 to 20 years, the mortality rate for sugar maple (Acer saccharum Marsh.) has been estimated to have doubled (Miller, personal communication). Crown dieback of unknown cause has become so widespread, it is difficult to locate healthy trees of this species in Syracuse. These and other problems, some unique to the urban environment, aroused concern at the College of Environmental Science and Forestry for trees in metropolitan areas. Three coordinated projects have resulted, involving detailed studies of street trees in the cities of Rochester and Syracuse, New York. The first is concerned with developing aerial photographic techniques for expeditious detection of stressed trees. The second involves the assessment of environmental and biotic factors associated with declining maples through coordination of aerial photography and intensive ground observations of growth, health, and site conditions. The third project is concerned with the improvement of urban trees through the selection and breeding of trees that have survived one generation in the urban environment. There is some question, however, whether the phenotypic variation among the surviving trees is sufficient to serve as the genetic base for improvement by artificial selection. The purpose of the present study was to devise methods for characterizing the structure of urban tree populations and for estimating the population parameters.

STRUCTURE OF URBAN STREET TREE POPULATIONS

Results of a 1974 census of street trees in Poughkeepsie, New York conducted by Cary Arboretum of the New York Botanical Garden provided the materials for this study. The data included location, measures of growth and health, and the environmental conditions for each tree. True population parameters were calculated by computer for height and stem diameter at breast height (d.b.h.) for each of the five most common species in the older surviving populations and simulation methods were utilized to determine an efficient, reliable method for estimating these parameters by survey sampling procedures. Additional information provided by

these methods includes the species and cultivars present, their incidences and their patterns of dispersion. Though this study is primarily concerned with the older trees, the methods are applicable for all components of street tree populations. Only those aspects of population structure directly related to the sampling procedures that appear to best characterize these populations, however, will be presented.

The population of Poughkeepsie has been stratified in two ways. One is by age, with a species classified as "older" if the average height \geq 15 feet and average d.b.h. \geq 5 inches and "younger" if the average size is smaller in one or both traits. The eight most common "older" species listed by number of trees and percentage of the total population are given in Table 1. These species are comprised almost wholly of older, established trees except for red maple (*A. rubrum* L.). About 20% of the trees of this species fall into the "younger" tree class and occur in some of the more recently developed areas of the city as well as areas of urban renewal and redesign. The six species and cultivars comprising the "younger" group (Table 1) reflect a marked change in tree preferences for street plantings. Some of these replaced American elms, but most are present in more recent developments and in areas of urban renewal and redesign.

A second stratification was by "land use," according to city zoning designations, and include: low density residential, medium to high density residential, and commercial industrial. The commercial and industrial zones were combined because of the small areas represented by each in Poughkeepsie and because of the scarcity of street trees in these sections of the city. Even so, the numbers of red and silver maples and basswood (5, 5, and 8, respectively), are too small for meaningful comparisons between the commercial-industrial stratum and the other strata for these species.² Comparisons of the true population parameters, μ and σ^2 , for stem height and diameter between the low density residential and the medium-high density residential strata revealed only small differences except for red maple. The red maple difference is likely attributable to the non-random distribution of younger trees among strata. Twenty-nine of the 36 "younger" trees occur in an area of urban renewal with multiple-dwelling public housing along the riverfront, i.e. the medium-high density residential stratum. They make a large contribution to the larger variances that were obtained for the 82 trees in this stratum compared with that for the 84 red maples in the low density residential stratum. It was concluded, however, that stratification by land use would have little value, and the data were pooled for each species.

The pattern of dispersion of trees could affect the sampling procedures, especially for the less common species and cultivars. Norway Maple (A. platanoides L.) and sugar maple are sufficiently common and widespread throughout the city so that most sampling procedures would provide reliable estimates of incidence, dispersal and population parameters. The trees of both species, however, tend to occur in "clusters" along a street or block, but the clusters are many and widely dispersed. The next three commonest species among the "older" trees, red maple, silver maple (A. saccharinum L.) and basswood (Tilia americana L.), are considerably less frequent, but also tend to occur as clusters with 50% or more of each species present in this pattern of planting. These patterns can be seen in Figure 1 which shows species incidence along residential streets in one of the older sections of the city. The remaining three species in the "older" group each represent less than 1% of the total population and occur mostly as widely scattered single trees. Some of these are shown in Figure 1.

The six species and cultivars in the "younger" group exhibit an even greater tendency of clustering, with 60% of the littleleaf linden (Tilia cordata Mill.) and 80% or more of the other five occurring in this planting pattern. This can be seen in Figure 2, which includes an area of urban renewal in the riverfront section and an area of urban redesign in the vicinity of the downtown mall. High proportions of these species and cultivars occur in these areas, with small numbers in newer developments and replacement plantings.

The results of this analysis of the Poughkeepsie street tree population clearly indicate that a sample survey method for characterizing urban street tree populations must accommodate the practice of planting the trees in "clusters" as well as widely scattered single specimens. Since members of a cluster are likely of common origin, i.e. from the same group of nursery stock, and share a similar environment, one might expect less variation to be exhibited in comparisons of members of the same cluster than between clusters. The sampling procedure herein proposed provides reliable information on the nature of the street population as well as unbiased estimates of true population parameters.

SAMPLING DESIGNS FOR ESTIMATING VARIABILITY OF URBAN STREET TREE POPULATIONS

The objective of this portion of the study was to devise a workable sampling scheme for estimating the variance, σ^2 , of traits of urban street trees. An estimator which was unbiased and which had a minimal variability was

sought. Our approach is based on the fact that the true population parameters for Poughkeepsie street trees are known. The results of various computer simulated sampling surveys, therefore, could be compared with these known values and the schemes evaluated. The true population means and variances for stem height and diameter for each of the five commonest "older" species and the total number of trees comprising the total population of each species are given in Table 2.

Limitations imposed upon the survey methods were that the computer simulated procedure must mimic one that would be feasible for a survey crew walking down a street measuring trees and recording their observations. And secondly, in their design, consideration must be given the actual structure of the Poughkeepsie population since the success of the scheme and the accuracy and precision of the estimates are dependent upon the species' frequencies and distribution.

The proposed sampling scheme is based upon three variables:

m--the number of streets randomly selected for the survey from the 275 streets in Poughkeepsie,

k--the sampling interval for trees of each species,
i.e. if k= 1, every tree of that species would
be sampled:

if k= 2, every second tree would be sampled, etc.

n--the total number of trees of a given species in the sample population.

In a given sampling scheme, one or more of these variables could be fixed; moreover, the fixed value for a particular variable such as k could differ for the five species.

To illustrate the general scheme, the survey crew would sample every k_i th Norway maple, every k_j th sugar maple, etc. encountered as they proceeded along each of m randomly selected streets. The number of trees sampled for each species, e.g. n_i Norway maple, n_j sugar maple, etc., would vary because of the different number of trees of each species on these streets and because the sampling interval could vary among species, i.e. k_i ≠ k_j, etc. Estimates of σ^2_H and σ^2_D would then be calculated from the sample population for each of the five species.

Each sampling scheme was repeated by computer simulation forty times to yield forty variance of stem height estimates (s^2_H) and forty variance of stem diameter estimates (s^2_D). The mean and standard deviation of the forty estimates for

each of these variance parameters were computed to check for bias and to determine the degree of variability among the estimates. All the schemes investigated will not be presented, only the one that appears most promising.

Computer survey simulations were completed for each combination of \underline{m} from 30 to 150 at intervals of 10 and values of \underline{k} of 1, 3 and 10. Additional simulations with \underline{k} values of 2, 5, 7, 15 and 20 were conducted for \underline{m} values of 50, 100 and 150. Altogether 54 combinations of \underline{m} and \underline{k} were used in computer simulated surveys for each of the five species, with 40 iterations of each combination. These provide information on the effect of varying \underline{m} and \underline{k} on sample size (\underline{n}) and on the variability exhibited by the forty independent estimates of σ_H^2 and σ_D^2 for each of the five species.

The results of the computer simulations are presented only in part because of the extensiveness of the data and because the general trends exhibited in all of the results due to varying \underline{m} and \underline{k} are exhibited by these data. The results for stem height in Norway maple are presented in Table 3 for illustrative purposes. The results of the computer iterations for a particular sampling scheme are given in the cell formed by the column for \underline{m} and the row for \underline{k} , with the upper number the standard deviation of the forty estimates of σ_H^2 and the lower number the average sample size, \bar{n} .

Note the effect on the variability of the estimates (upper numbers) and on the average sample size (lower numbers) as \underline{m} and \underline{k} change. If \underline{k} is held constant, e.g. $\underline{k} = 1$, the standard deviation of the σ_H^2 estimates decreases from 12.51 to 5.09 as \underline{m} increases from 30 to 150 as shown in Table 3, and the mean sample size increases from 478 to 2396. These results are not unexpected since sample size should increase if the number of streets sampled is increased. Since a larger sample will provide a more precise estimate of the true population variance, less variation in the variance estimates should occur in repeated simulations. Varying \underline{k} and holding \underline{m} constant has the converse effect, i.e. as the sampling interval increases, the mean sample size decreases and variability among the variance estimates increases. For example, if \underline{m} is held constant at 50 and \underline{k} increases from 1 to 20, the standard deviations of the σ_H^2 estimates increases from 9.80 to 16.23 and sample size decreases from 758 to 80 as given in Table 3. Again these results are not unexpected as the variability of the estimate should increase as sample size decreases.

The most important trend, however, can be seen if both k and m vary but sample size is held constant. Paired combinations of cells in Table 3 can serve as examples. The first pair of cells is for $k = 1$ and $m = 40$ and for $k = 3$ and $m = 110$, each with an average sample size (\bar{n}) of 643. Note that the variability of the σ_H^2 estimates is more than halved by sampling every third Norway maple on 110 streets rather than every one encountered on 40 streets. A second pair of cells is for $k = 3$ and $m = 50$ and for $k = 7$ and $m = 100$, each with $\bar{n} = 294$. In this example the standard deviation of the σ_H^2 estimates is decreased by about 35%, i.e. from 11.51 to 7.43 by a larger sampling interval and a greater number of streets. The general effect of increasing both the number of streets (m) and the interval between sample trees (k) but holding the sample size (n) constant is marked reduction in the variability of the variance estimates. The sampling scheme to be proposed is based upon this result. One disadvantage to the improvement of the estimate by this method is of no consequence in a computer simulated survey, but would be of importance to a survey crew on foot. That is the distance to be walked and the total time for the survey will increase as the number of sampled streets (m) increases. Therefore, some compromise must be made between the precision of the estimate and the time and cost factors involved in the actual street surveys.

The pattern of distribution of street trees appears to provide the answer to the question of why the combination of a larger number of sample streets and a greater sampling interval increases the accuracy of the estimate of the true population variance. Recall that trees of a given species tend to occur in clusters. Furthermore, members of the same cluster are likely to exhibit less variation for a trait than members of different clusters. Sampling from groups of phenotypically similar trees will tend to give a more biased estimate of the total variation for a trait among all trees of that species in the entire city. In this case, it will be underestimated. This accords with theories of cluster sampling concerned with the estimation of the population mean, μ , (Mendenhall et al, 1971). It can be demonstrated that samples drawn from clusters² with little variation

² In this paper the word "cluster" is used, for the most part, according to the layman's definition, relating to the distribution or dispersion of individuals in groups. In this paragraph, however, it is used according to the definition in sampling statistics, i.e. a cluster is a group in a larger population selected at random so that the sample population is composed of randomly selected groups (Mendenhall et al, 1971). In this study, portions of streets were selected randomly and are the clusters.

tend to lead to estimates of μ , i.e. the \bar{x} , with higher variation than samples from clusters with high variation formed from the same population. This principle appears to apply to the streets in this study which act as clusters in estimating the population variance, σ^2 . The larger sampling interval, therefore, minimizes the effect of the within cluster variation by reducing the number of similar phenotypes in the sample.

Another method of comparison of the results in Table 3 suggests how one could decide the most efficient sampling scheme in terms of the actual street survey procedures for a given level of precision in the estimate of the true variance. It can be seen that six combinations of k and m result in about the same standard deviation in the σ^H estimates. These are $k = 1$ and $m = 80$ or 90 , $k = 2$ and $m = 100$, $k = 3$ and $m = 90$ or 100 , and $k = 10$ and $m = 120$. Also note the differences in the mean sample sizes (n), with $n = 278$ for $k = 10$ and $m = 120$ the smallest. Since the measurements and the recording of information for sample trees require the most time in a street survey, limiting sample size without sacrificing precision of the estimator would increase the efficiency of the survey. It should be noted, however, that even though time spent walking between sample trees is relatively small, increasing both k and m increases the walking time and must be considered in the decision of the sizes of these variables. In looking at the six combinations of k and m that exhibit about the same precision in the variance estimate (see above), it would appear that the scheme with $k = 10$ and $m = 120$ with the smallest average sample size (n) = 278 is the best choice. The much smaller number of trees to be measured compared with the other five more than compensates for the larger number of streets to be walked. For example, in comparison with the $k = 1$ and $m = 80$ procedure, the 80% reduction in sample size (278 vs. 1278) obviously offsets the disadvantage of a 50% greater distance to walk (120 vs. 80 streets), especially when these factors are weighted according to their relative time requirements. The scheme with $k = 3$ and $m = 90$ with $n = 521$, which has exactly the same precision for the estimated variance as the preferred scheme, would appear the next best choice. In fact, it might well be the best if few measurements and observations were required for sample trees. The time spent at almost twice as many trees (521 vs. 278) would have to be compensated by the fewer streets to be walked (90 vs. 120). These comparisons clearly show that the selection of m , the number of sample streets or clusters, and k , the sampling interval, and their effect on (n), the sample population size, are critical in designing an efficient but reliable survey sampling scheme. The size of each variable must be weighed in relation to the required precision for the estimated parameter and to the efficiency of the actual street survey.

The amount of variability in the estimate of the true variance, i.e. the precision of the estimate, that can be decided before a sampling scheme can be designed. This has been approached by using a method employed by Namkoong and Roberds (1974) to measure the relative variability in estimated genetic variance (σ_A^2). They calculated the Coefficient of Variation for the variance estimates and considered estimates with C.V. $\leq 1/2$ as good. At this level, σ_A^2 will be larger than twice its standard error of estimate. Applying this to the present study, the values of C.V. for the six variance estimates discussed above would be equal to or less than .06, values much smaller than the value for this statistic suggested by Namkoong and Roberds. This suggests that a much greater variability in the estimate could be permitted. This could easily be achieved by reducing the sample size, which would also greatly increase the efficiency of the sampling scheme.

The Coefficient of Variation has also been employed to assist in making decisions on the sizes of the three variables, m --number of randomly selected streets or clusters. k --the sampling interval, and n --sample population size. Comparisons were made of the Coefficient of Variation for the various computer simulated sampling schemes for both stem height and diameter for each of the five species. It was found that a minimum value of $m = 50$ would provide variance estimates with a C.V. ≤ 50 for both traits in all five species. The larger values of C.V. occurred for the less common species, which is to be expected because of the smaller sample sizes. For Norway and sugar maple with $m = 50$, increasing the sampling interval (k) to 10 and 3, respectively, to reduce sample sizes to 113 and 70, respectively, still resulted in a C.V. $\approx .20$. The C.V. values increased sharply in most cases for values of m less than 50, and of course, sample size was markedly reduced. Increasing m above 50 results in a greater precision, C.V. decreases and sample size increases, but a point of diminishing return is generally evident when m is approximately 100. Certain exceptions to this were obtained for less common species. Nevertheless, in this study reasonably reliable variance estimates were obtained for stem height and diameter for both silver maple and basswood with $m = 50$ and $k = 1$ even though they are relatively rare (incidence approximately 2%) and the sample sizes were small, 27 and 31, respectively. It would appear that the number of streets or clusters (m) should be at least 50 but not more than 100. A total sample size of about 100 appears sufficiently large for precise estimates of population variances, although much smaller sizes provided reasonably precise estimates. Finally k can be determined for each species on the basis of the total population size and species' incidence so that a sample population of 100 is obtained for the more common species.

For less common species and cultivars, every tree should be sampled, i.e. $k = 1$. If considerable environmental variation occurs, it would be advisable to increase the number of clusters (m) as well as sample size (n). If sample size must be limited or held constant, both k and m could be increased.

To illustrate how this sampling scheme works, results that might be obtained by a survey crew using this scheme are given in Table 4. The true population variances are also given for easy comparisons. The number of streets (m) selected at random for each species was 100. The sampling intervals (k) is different for each species because of different species densities and for red maple, because of the peculiarity in its distribution previously discussed. If the estimates of the variance for each trait (s_H^2 and s_D^2) are compared with true variances (σ_H^2 and σ_D^2) for each species, striking similarities are evident except for both traits for red maple and the variance of diameter for basswood. None of the remaining differences are statistically significant. In fact, it can be shown that these estimated variance values are within one standard deviation of their respective true population variances.

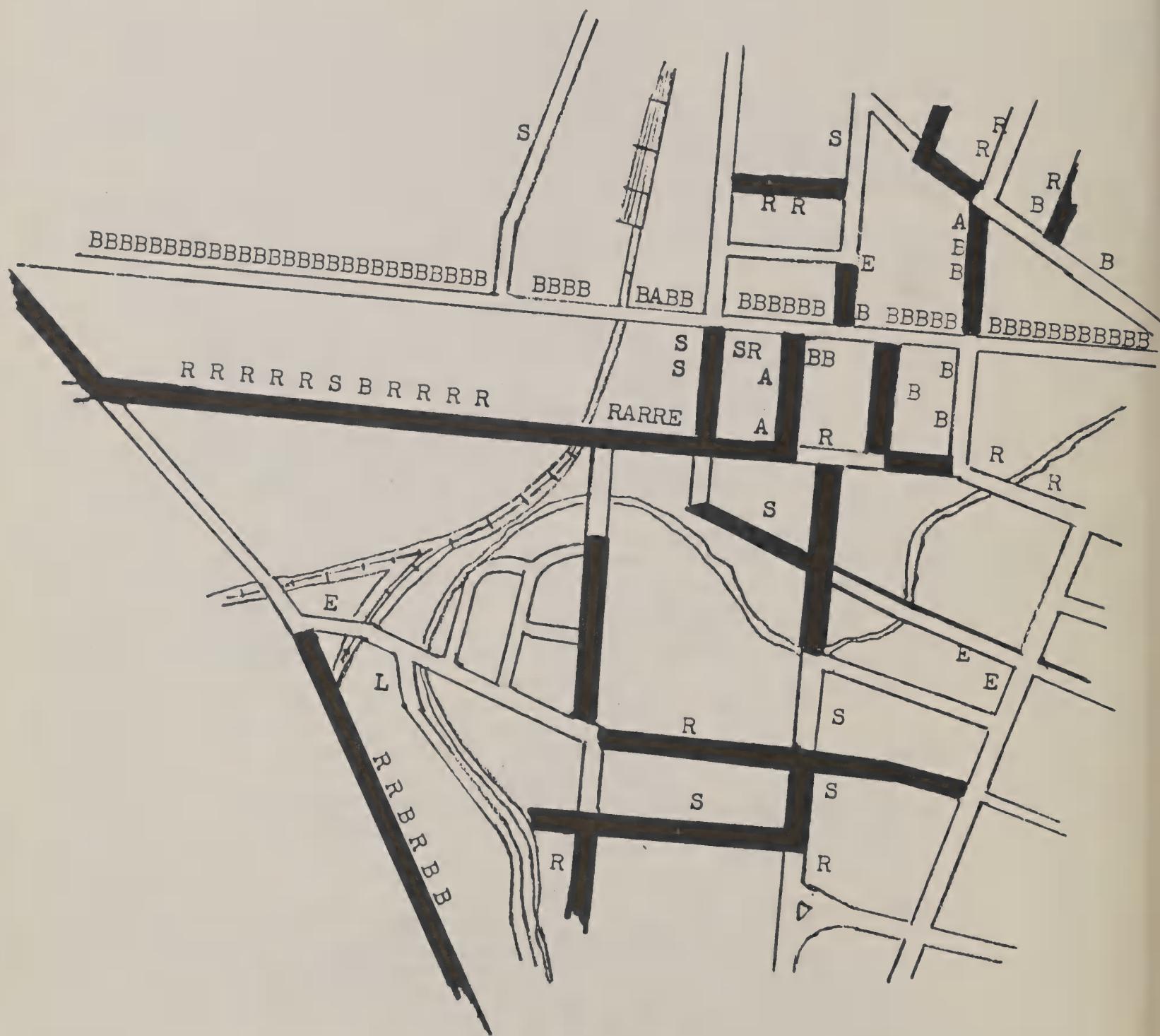
The results of this simulated survey clearly show that the proposed sampling scheme can be used to provide precise estimates of population variances, based upon a relatively small sample population. Though Poughkeepsie is a rather small city (approximately 32,000 population and area of four square miles) with a reasonably homogeneous environment in the lower Hudson River Valley, the proposed sample survey method should be equally applicable to other urban centers, even large ones, as long as tree species occur as clusters along the city streets.

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Figure 1

Distribution of common older street trees.



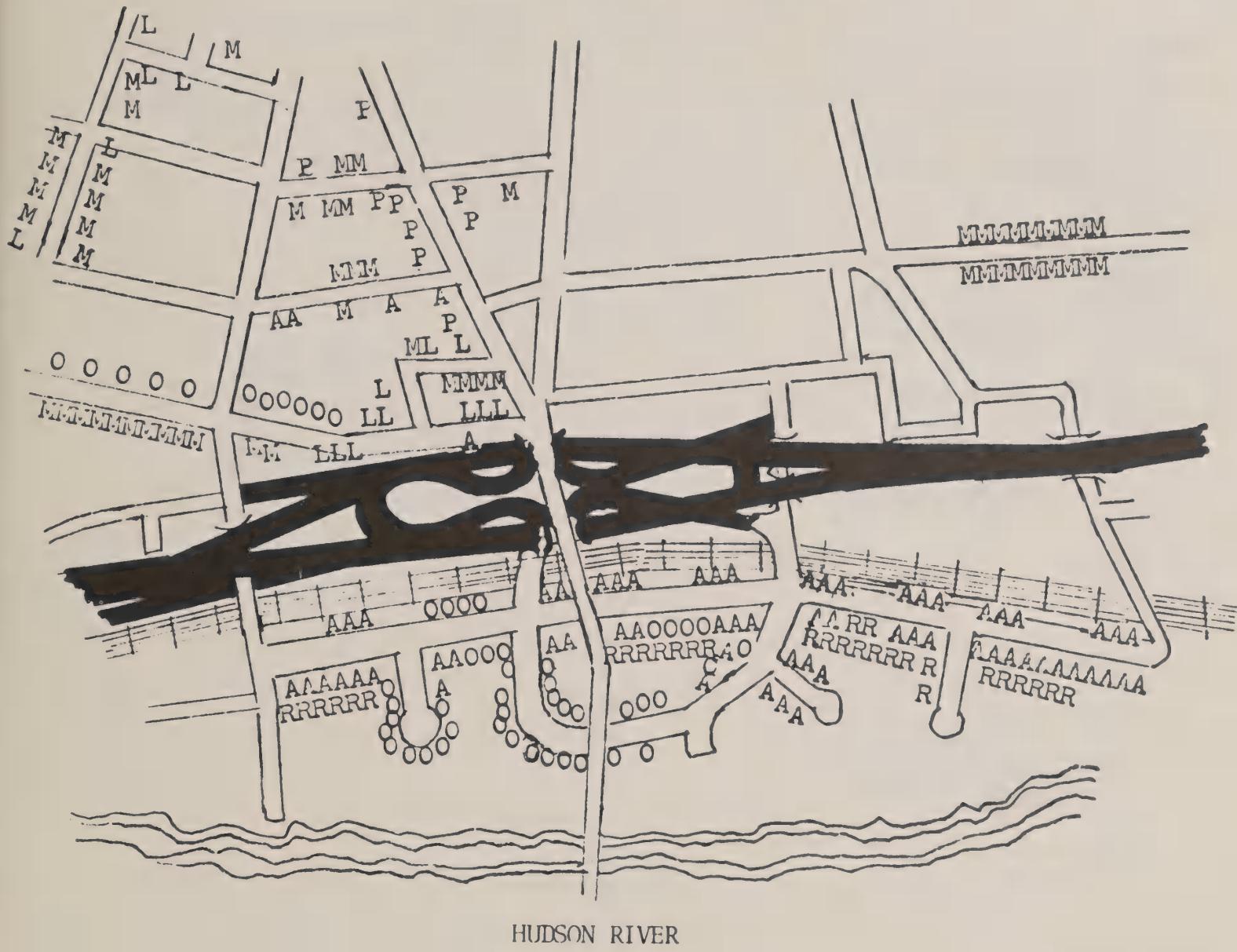
Legend

Each letter represents one tree; a shaded street indicates one or more sugar maple per block; Norway maple not shown but is cosmopolitan.

White ash	A	Black locust	L
Basswood	B	Red maple	R
American elm	E	Silver maple	S
Sugar maple	[shaded area]		

Figure 2

Distribution of recent street tree plantings.



Legend

Each letter represents one tree except near the riverfront where space limitations prevented showing all trees.

Marshall's seedless green ash	A	Pin oak	O
Littleleaf linden	L	<u>Prunus</u> spp.	P
<u>Malus</u> spp.	M	Red maple	R

TABLE 1

Common street trees of Poughkeepsie, New York

Name

<u>Older Trees</u>	Number	Per-cent	Distribution
Norway maple <i>(Acer platanoides L.)</i>	4334	59	Ubiquitous
Sugar maple <i>(A. saccharum Marsh.)</i>	834	11	Clusters
Red maple <i>(A. rubrum L.)</i>	193	3	"
Silver maple <i>(A. saccharinum L.)</i>	149	2	"
Basswood <i>(Tilia americana L.)</i>	156	2	"
White ash <i>(Fraxinus americana L.)</i>	52	0.7	Scattered
American elm <i>(Ulmus americana L.)</i>	44	0.6	"
Black locust <i>(Robinia pseudoacacia L.)</i>	32	0.4	"
<u>Young Trees</u>			
Malus spp.	813	11	Clusters
Pin oak <i>(Quercus palustris Muenchh.)</i>	97	1	"
Littleleaf linden <i>(T. cordata Mill.)</i>	88	1	"
Marshall's eedless green ash <i>(F. subintegerrima</i> var. <i>lanceolata</i> 'Marshall')	85	1	"
Cherry <i>(Prunus spp.)</i>	40	0.5	"
Goldenraintree <i>(Koelreuteria paniculata Laxm.)</i>	35	0.5	"
<u>Other Trees</u>	420	5.7	
Total Population	7372	100%	

TABLE 2

True population parameters for stem height in feet and diameter in inches for the five most common "older" street tree populations in Poughkeepsie.

Species	Number	Incidence	Population parameter			
			Height	Diameter	μ_H	σ_H^2
Norway maple	4334	59			32.2	121.0
Sugar maple	834	11			43.7	158.6
Red maple	193	3			37.5	238.2
Silver maple	149	2			52.5	153.7
Basswood	156	2			45.7	136.7
Others	1706	23			-	-
Total Population	7372	100%				

TABLE 3

Standard deviations of σ_H^2 - estimates (upper number) and average sample population, \bar{n} , (lower number) for Norway maple based upon forty computer simulations of each sampling procedure.

Sampling interval (k)	Number of streets (m)												
	30	40	50	60	70	80	90	100	110	120	130	140	150
1	12.51	13.20	9.80	7.00	8.11	6.75	6.81	6.03	5.36	5.13	4.65	4.27	5.09
1	478	643	758	945	1130	1278	1417	1591	1750	1927	2076	2246	2396
1	2		10.64					6.72				3.87	
2			436					841				1231	
1	3	15.47	12.10	11.51	10.09	8.84	8.61	6.79	6.78	6.21	6.42	5.03	4.91
3	180	235	294	343	417	457	521	582	643	691	757	827	870
5			11.42					7.36				3.85	
5			190					378				562	
7			14.57					7.43				3.96	
7			147					294				443	
10	1527	14.02	14.53	10.52	9.32	8.88	9.30	9.61	7.16	6.79	7.00	6.12	4.01
10	71	94	113	136	166	184	208	279	253	278	299	323	347
15			21.75					10.17				6.12	
15			90					183				273	
20			16.23					10.23				5.92	
20			80					160				240	

TABLE 4

Estimated variances of stem height (ft.) and diameter (in.) from a computer simulated sample survey of Poughkeepsie street trees.

m = number of streets, k = sampling interval, and n = sample population size

Species	<u>m</u>	<u>k</u>	<u>n</u>	Population parameter			
				Variance of height	(Estimate)	(True)	
				s_H^2	σ_H^2	s_D^2	σ_D^2
Norway maple	100	10	244	114.8	121.0	34.1	34.9
Sugar maple	100	3	127	167.7	158.6	51.7	49.6
Red maple	100	10	34	117.8	238.2	40.3	86.0
Silver maple	100	1	58	120.8	153.7	106.1	92.8
Basswood	100	1	40	150.5	136.7	43.2	25.7

JAPANESE BEETLE PREFERENCES
AMONG LINDEN CULTIVARS¹

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ABSTRACT.--Defoliation of four linden cultivars by Japanese beetles (Popillia japonica) was compared on three dates. Tilia cordata 'Greenspire' was damaged much more than T. cordata 'June Bride'. T. americana 'Redmond' was fed upon nearly as much as the 'Greenspire' lindens, but T. tomentosa (Princeton strain) was damaged very little. 'Greenspire' lindens growing along city streets about one mile away were not defoliated at all. Differences in beetle preferences seem to be important only if lindens are to be planted near lawns, where beetles can multiply in the sod. Metro. Tree Impr. Alliance (METRIA) Proc. 1:44-48, 1978.

INTRODUCTION

The Japanese beetle, Popillia japonica Newman, has spread through most of the eastern United States since its introduction to New Jersey in 1916. In the Northeast, partially developed grubs overwinter in the soil (Johnson and Lyon, 1976); in the spring they start feeding on fibrous roots and organic matter until about an inch long (Becker, 1938). The mature grub then pupates and adults emerge a few days later - about the third week in May in North Carolina to early July in New England. The adult lives for 30-45 days and each female lays 40-60 eggs. Eggs hatch in about two weeks and the small grubs feed on rootlets until winter (Johnson and Lyon, 1976).

¹ Research supported in part by the USDA Northeastern Forest Experiment Station through the Pinchot Institute Consortium for Environmental Forestry Studies. Journal Paper No. 5146 of the Pennsylvania Agricultural Experiment Station. Center for Air Environment Publication No. 446-76.

Adult beetles feed on about 300 species of plants, chewing out the tissue between veins. They prefer plants in direct sunlight and usually start at the top and work downward. The amount of damage to a plant depends on its attractiveness to the beetle, the number of beetles in the area, and local conditions (Fleming, 1962). Adult beetles can completely defoliate a tree, which impairs the tree's health and seriously reduces its aesthetic value.

In places where Japanese beetles could cause serious damage it would be advantageous to plant trees that are resistant. This paper reports the relative preferences of Japanese beetles for four linden cultivars.

MATERIALS AND METHODS

During the summers of 1975 and 1976 Japanese beetles were observed feeding in a small plantation of ash and linden cultivars located on the Blue Golf Course at The Pennsylvania State University. The plantation was established in 1973 to study effects of air pollutants, and consists of three randomized blocks, each with 7 ramets of each of the following clones:

- Fraxinus americana 'Rosehill' -- Rosehill Ash
- F. excelsior 'Hessei' -- Singleleaf European Ash
- F. pennsylvanica 'Marshall's Seedless' -- Marshall Seedless Ash
- F. pennsylvanica 'Summit' -- Summitt Ash
- Tilia americana 'Redmond' -- Redmond Linden
- T. cordata 'Greenspire' -- Greenspire Linden
- T. cordata 'June Bride' -- June Bride Linden
- T. tomentosa 'Silver Linden', grafted Princeton Strain

All the trees were about the same size (approximately 10' tall), except the silver lindens, which had died back after planting and were mostly basal sprouts (approximately 3' tall).

In June it was noticed that the Greenspire lindens were being severely damaged by Japanese beetles, but the ash were untouched. The other lindens were being attacked less than the Greenspires. The beetles were defoliating the tops of the trees and working their way downward.

On July 10, 1975, the damage to each linden was recorded. For each tree the percent of leaves attacked and the percent of area removed from an average leaf was estimated, both to the nearest 10%. These two figures were multiplied to give a total percentage of foliage removed. That afternoon all trees were sprayed by golf course employees with insecticide. This treatment protected the trees for a few days, but within several days more beetles resumed feeding on the lindens.

On August 20 the amount of foliage subsequently removed was recorded by subtracting the percentage of foliage removed on July 10 from the total percentage of foliage removed by August 20. Data were taken again on July 16, 1976.

RESULTS

An analysis of variance was performed on each set of data. All three analyses showed the clones as a significant source of variation (Table 1). There was a significant replicate effect in data from July 16, 1976 and a small replicate x clone interaction on the data of August 20, 1975.

Cultivar means are shown in Table 2. The Greenspire lindens received the most damage followed closely by the Redmond lindens. June Bride lindens consistently ranked third, followed by the silver lindens with the least amount of damage. Duncan's Modified Least Significant Difference test showed most of the cultivar means significantly different from each other; but on August 20, 1975, and July 16, 1976, Greenspires were not significantly different from the Redmonds.

DISCUSSION

Fleming (1962) reported that Japanese beetles feed extensively on American linden (Tilia americana) and littleleaf linden (T. cordata) but only lightly to moderately on silver linden (T. tomentosa), and not at all on either green or white ash. This is totally consistent with our observations. Near Wooster, Ohio, T. americana 'Redmond' has been observed as the cultivar of Tilia first attacked and most severely damaged.¹ In contrast, our Greenspires were damaged significantly more than the Redmonds in the beginning of the summer of 1975, but received the same amount of damage in the latter part of that year and in 1976. This difference may be due to our method of observation. Redmonds seemed to retain the brown skeletons of consumed leaves longer than Greenspires, which makes a tree appear worse than when these leaves fall off. In collecting our data the differences in retention of dead leaves was ignored.

Under our conditions T. cordata 'Greenspire' and T. americana 'Redmond' were highly preferred by Japanese

¹ Personal communication, April 6, 1976, T. L. Ladd, Jr., Research Leader, Japanese Beetle Research Laboratory, Ohio Agriculture Research and Development Center, ARS, USDA, Wooster, Ohio.

Table 1. Mean squares from analyses of variance of percent foliage removed from linden cultivars by Japanese beetles.

Source	D.F.	July 10, 1975	August 20, 1975	July 16, 1975
Replicates	2	4.9 n.s. ^a	260.7 n.s.	664.4*
Clones	3	7547.0*	6376.6*	2530.5*
R x C	6	48.9 n.s.	416.2*	145.4 n.s.
Error	72	37.6	176.6	125.5

^a n.s. not significant

* significant at 95% level

Table 2. Percent of foliage removed from linden cultivars by Japanese beetles.^a

Cultivar	July 10, 1975	August 20, 1975	July 16, 1975
Greenspire	44.0	44.6	28.2 b
Redmond	11.8	41.1	23.0 b
June Bride	7.3	22.0	18.5
Silver	1.9	7.3	4.4

^a Values within dates were significantly different from each other at the 95% level except those followed by the same letter. Values between dates were not compared statistically.

beetles, T. cordata 'June Bride' was preferred much less, and T. tomentosa was preferred the least. These rankings depend on the local conditions and vegetation. Had there been an abundant source of a more preferred food (roses, for instance) the lindens may have been attacked much less. Also, beetles usually fly only short distances to find food (Fleming, 1962), and less than a mile away Greenspire lindens growing along city streets were not defoliated at all. It seems that these differences in preferences may only be important if the lindens are planted near areas such as lawns, where the beetles can multiply in the sod.

Japanese beetles may be controlled successfully by insecticides such as Sevin (Carbaryl), but repeated spraying is often necessary and costly. Biological control methods have been investigated, and a disease-causing bacterium is commercially available (Johnson and Lyon, 1976). The best method of "control" is to avoid planting preferred trees where Japanese beetles are a problem.

The large difference in damage between the two cultivars 'Greenspire' and 'June Bride' indicates that intraspecific variation in attractiveness to Japanese beetles exists in Tilia cordata. Schreiner (1949) reported large variations in Japanese beetle damage among individual Populus hybrids of the same parentage. This supports the idea that attractiveness to Japanese beetles is genetically controlled and that it would be possible to exploit natural variation, or variation among hybrids, and breed beetle-resistant cultivars.

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SUSCEPTIBILITY OF HONEYLOCUST (GLEDITSIA) SPECIES
TO MIMOSA WEBWORM

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ABSTRACT.--Seedlings of 13 taxa of Gleditsia were deliberately exposed to high natural populations of mimosa webworm during 1974 and 1975. The only species exhibiting high resistance (bordering on immunity) was G. fera from Hong Kong, which is of doubtful hardiness over much of the United States. G. amorphoides, the only South American species, also appeared to be somewhat resistant. No meaningful levels of resistance were found among hardy species. Thus, interspecific hybridization may not be very useful in developing webworm-resistant cultivars. It is suggested that mass-screening of thornless seedlings of G. triacanthos may be the most feasible method of early selection for resistance to webworm in any long-term improvement program. Metro. Tree Impr. Alliance (METRIA) Proc. 1: 49-56, 1978.

INTRODUCTION

Honeylocust (Gleditsia triacanthos L.) has become, in recent years, one of the most extensively grown, vegetatively-propagated landscape trees in the United States. The thornless types (G. triacanthos f. inermis Schneid.¹) have, of course, been preferred for environmental planting. Most of the selections have also been essentially fruitless, producing mostly male flowers. The cultivar 'Stephens', in 1940, was the first American-named thornless cultivar, 'Moraine', in 1949, was the first patented cultivar (Wagenknecht, 1961). Since then, nearly 20 cultivars have been named or patented. Thousands of thornless honeylocust trees, including a high percentage of selected cultivars, are planted annually in urban and suburban areas.

¹ Botanical authority according to Isley (1975)

The increase in popularity of honeylocust has, unfortunately, been paralleled by the spread of a destructive insect pest, the mimosa webworm. This insect was first discovered in 1940 in the United States infesting leaves of "mimosa" (*Albizia julibrissin* Duraz.) in Washington, D. C. Clarke (1943) named the insect *Homadaula albizziae* and suspected that it was of Indo-Australian origin. Subsequent study (Clarke, 1968) has revealed that the webworm is identical to an insect described from China in 1935. Thus, the correct name for the mimosa webworm is *Homadaula anisocentra* Meyr. (Caradja and Meyrick, 1935).

Wester and St. George (1947) were the first to report honeylocust as a host plant for the mimosa webworm, and their work remains the authoritative study of the life cycle of this insect. They also reported that from 1940 to 1946 the insect had spread 100 miles south and some 50-65 miles north of the District of Columbia. A distribution map presented by Clarke (1968) and a recent updating (USDA, 1975) show that continuing infestations have been reported from 28 states. This area runs roughly from the Massachusetts-Rhode Island border west to central Nebraska, south to northern Texas, and east through the Gulf States to Florida. Several counties in northern California also have severe infestations.

Because of climatic control of population development, the present distribution is likely to remain relatively static over the next decade or so, except for "border" movement. However, the distribution does indicate that an origin in China is far more likely than, as once suspected, an Indo-Australian origin.

Opinions vary from person to person and region to region as to whether the webworm is of sufficient importance to justify chemical control methods or the development of resistant trees. The necessity of three spray applications per year for complete control of the insect normally is a deterrent to an effective control program. Trees growing in lawns are especially prone to late summer defoliation, because the ground cover affords good protection for the overwintering pupae. Insect populations may not be sustained in planting areas surrounded by concrete and asphalt because of the lack of overwintering sites. Under optimum conditions, however, the webworm can be a destructive pest.

Honeylocust cultivars vary in apparent resistance to the mimosa webworm. Schuder (1973) reported that 'Moraine' was significantly more resistant than four other cultivars when statistically tested under natural infestation conditions over a 10-year period. Our observations of these same cultivars (nonreplicated) at the National Arboretum are in agreement with Schuder's results. Certainly, the most effective long-

term control method would be the development of more highly resistant trees with varied growth habits and growth rates.

One approach to the creation of webworm-resistant trees might be hybridization between the best forms of G. triacanthos and some other species that had high resistance or immunity. However, we have very little knowledge concerning the potential resistance or susceptibility in exotic Gleditsia species. Even though there are about 13 species of Gleditsia besides G. triacanthos (Gordon, 1966), they are seldom planted, even in arboreta or botanical gardens.

The other native American species of honeylocust is G. aquatica Marsh. (water locust), a native of South-Central United States. Natural hybrids between this species and G. triacanthos have been recognized as G. x texana Sarg. and have been reported from Texas, Louisiana, Mississippi, and Indiana. No species are native to Europe, but G. caspica Desf. (Caspian locust) occurs south and southwest of the Caspian Sea in the Transcaucasus and Northern Iran. G. japonica Miq. may occur in Japan and China, and var. koraiensis Nakai has been described from Korea. G. assamica Bor is a little-known species from Northern India, and G. rolfei Vid. is found in Taiwan, Viet Nam, the Philippines, and the Celebes. The remainder of the Asiatic species are native to China, including G. australis Hemsl., G. delavayi Franch., G. fera (Lour.) Merr., G. microphylla Gordon (=G. heterophylla Bunge), G. macracantha Desf., and G. sinensis Lam., all of which are listed by Gordon (1966). Another Chinese species, G. melanacantha Tang & Wang, has recently been described in a Chinese "Flora" (Institute of Botany of the Chinese Academy of Sciences, 1972), and we have identified an unknown tree growing at the U. S. plant Introduction Station in Glenn Dale, Maryland, as that species. One species, G. amorphoides (Griseb.) Taub., is found in Argentina, Uruguay, and Paraguay in South America. Although Rehder (1940) mentioned a species from tropical Africa (G. africana Welw. ex Benth. from Angola), this species has been re-assigned to another genus.

The exotic species are seldom planted because of their poor or unknown adaptability and ornamental inferiority, and no thornless forms have been widely propagated. At least three of the Chinese species were originally described from cultivated specimens in Europe, and data on their native habitats are sketchy. In addition, the taxonomic confusion in botanical gardens and nurseries has led to many errors of identification (Bean, 1973).

Nevertheless, we have attempted to obtain seed, grow plants, and determine the webworm susceptibility of all available species of Gleditsia. The present study is part of an over-all investigation on the taxonomy, biochemistry, and genetics of this genus currently underway at the U. S. National Arboretum.

MATERIALS AND METHODS

Table 1 lists the primary seed sources for the species tested in this study. Seed was obtained from arboreta and botanic gardens throughout the world, either from their regular seed lists or through personal communication. Some 47 seedlots were received, and in most cases we obtained seed of a given species from two or more sources. Sources other than those in the table included gardens in France, Germany, Portugal, and Tunisia.

Because of the probable errors in identification mentioned previously, the seeds of each accession were weighed, measured, and color-coded, and a sample was saved for inclusion with herbarium specimens.

Seeds were soaked in concentrated sulfuric acid for one hour before sowing in the greenhouse in January-February, 1974. Data on germination, seedling growth habit, time of thorn production, time of production of bipinnate leaves, and other morphological and physiological traits were taken during the seedling stage. Seedlings were potted in 10-inch fiber pots and acclimated outdoors in a lathouse for two weeks before being placed in test locations prior to the period of emergence of adult webworm moths in the spring.

Seedlings of all species except G. amorphoides, G. fera, and G. microphylla were included in replicated tests at two locations on the Arboretum grounds in 1974 and 1975. One location was in a permanent open coldframe, where established trees of Albizia julibrissin and G. triacanthos in the vicinity were infested annually by the webworm. A temporary coldframe was erected at the second test location, where surrounding trees of A. julibrissin and A. kalkora Prain. were infested. After the potted seedlings were placed in the coldframe, a heavy mulch of wood chips was applied over the containers.

A single seedlot of each species was chosen for the major test. Each of these seedlots was represented by a two-tree plot in each of three replications at each location. The other seedlots were represented by at least one four-tree row at each location. Some 380 seedlings of 10 species were tested in this manner.

Seedlings of the aforementioned three species (G. amorphoides, G. fera, and G. microphylla) were judged to be too small in the spring of 1974 for inclusion in the major tests. Instead, a smaller test consisting of six two-tree plots of each species was set up in only one location.

Webworm infestation was checked every two weeks in 1974 using two rather subjective criteria: (1) percentage of compound leaves that were webbed, and (2) percentage of foliage destroyed. The webworm has two complete generations and a partial third in the Washington, D. C. area. The damage from the second-and-third-generation larvae is normally far worse than that caused by first-generation larvae. Therefore, observations were made at monthly intervals, only from June 15 to October 15, during 1975.

Because of suspected lack of cold hardiness in G. amorphoides, G. fera, and G. microphylla, six plants of each species were left in the outdoor coldframe during the winter of 1974-75 and six plants were taken up and overwintered in a cool greenhouse. A few surplus plants of G. macracantha and G. sinensis were also overwintered under glass. The plants that had spent the winter in the greenhouse were placed in the coldframe again at the beginning of the 1975 growing season.

RESULTS AND DISCUSSION

Webworm infestation during 1974, the first season of testing, was somewhat confounded by plant size and growth rate. In addition, there was a significant difference in infestation intensity between locations, with 78 percent of the plants in the temporary coldframe being colonized as opposed to 31 percent in the permanent coldframe. However, no seedlots of the hardy species were completely free from insect damage.

No infestation was noted in 1974 in the three slow-growing, potentially tender species (G. amorphoides, F. fera, G. microphylla) in the permanent coldframe. All plants of these species that were left outdoors over winter were killed back to the root collar. Most of these plants resprouted during 1975.

There were no "location" differences in webworm damage among hardy species in 1975. Nearly 100 percent of the seedlings of these species were infested at each location. Comparisons among species were based on the percentage of foliage infested on September 15, 1975. G. delavayi and G. japonica var. koraiensis showed less damage than the other species, but even in those seedlots the amount of infestation could be detrimental to the landscape value of larger trees. Most of the seedlings of G. japonica var. koraiensis were thornless, and could be referred to f. inarmata Nakai.

Plants of G. amorphoides, G. fera, G. macracantha, G. microphylla, and G. sinensis, which had been overwintered in the cool greenhouse, were tested in only the permanent

coldframe during 1975. On September 15, 1975, the G. macracantha and G. sinensis seedlings were heavily defoliated; G. amorphoides had more than 75 percent of its foliage intact; and G. fera was completely free of webworm damage. The poor growth and development of G. microphylla did not allow any reasonable assessments of potential insect susceptibility.

Table 2 gives the overall rankings of webworm susceptibility among the species and seedlots tested. A few individual seedlings appeared to be significantly less susceptible to webworm infestation than other plants of the same seedlots or species. This was especially evident in G. delavayi and G. x texana.

CONCLUSIONS

The results of this preliminary survey of resistance to mimosa webworm among Gleditsia species do not offer much hope for the development of superior, webworm-resistant cultivars through interspecific hybridization. The only species with apparently high and potentially transmissible resistance is G. fera, and this species is not winter-hardy in Washington, D.C.

The goals of a honeylocust improvement program must include insect resistance, rapid growth rate, thornlessness, and fruitlessness. Only G. aquatica, G. triacanthos, and G. x texana have exhibited the qualities of adaptability and growth required in a successful cultivar. Thornless individuals are well known in these species.

It is suggested that the most feasible technique for the production of improved cultivars of honeylocust would be the mass-screening of thornless seedlings under conditions allowing for constant high populations of the webworm. Initial selections after the second year of growth could be outplanted for long-term testing in areas where Albizia julibrissin and highly susceptible plants of Gleditsia species serve as webworm "reservoirs." During this testing period, observations could also be made on the incidence of mites, various plant bugs, gall midges, and the few fungal diseases known to occur on Gleditsia species. Finally, after flowering at age 10 or older, male trees or male-flowering branches could be isolated for further propagation of desirable material.

Table 1. Primary seed sources of Gleditsia species.

<u>Species</u>	<u>Aboretum</u>	<u>Country</u>
<u>amorphoides</u>	Buenos Aries	Argentina
<u>aquatica</u>	Morris Arboretum	Philadelphia, Pa., USA
<u>caspica</u>	Taschkent	USSR
<u>delavayi</u>	Taschkent	USSR
<u>fera</u>	Agric. & Fish. Dept.	Hong Kong
<u>japonica</u>	Aritaki Arboretum	Japan
<u>japonica</u> var. <u>koraiensis</u>	Forest Expt. Sta.	Korea
<u>macracantha</u>	Univ. Athens	Greece
<u>melanacantha</u>	U.S. Plant Intr. Sta.	Glenn Dale, Md., USA
<u>microphylla</u> (<u>heterophylla</u>)	Taschkent	USSR
<u>sinensis</u>	U.S. Plant Intr. Sta.	Chico, Calif., USA
<u>x texana</u>	Taschkent	USSR
<u>triacanthos</u>	various	U.S. and Foreign

Table 2. Susceptibility of Gleditsia species to mimosa webworm infestation in 1975.

<u>Percent Foliage Destroyed</u>	<u>Species</u>
None	<u>G. fera</u>
25%	<u>G. amorphoides</u>
25-50%	<u>G. delavayi</u> , <u>G. japonica</u> var. <u>koraiensis</u>
50%	<u>G. aquatica</u> , <u>G. caspica</u> , <u>G. japonica</u> , <u>G. macracantha</u> , <u>G. melanacantha</u> , <u>G. sinensis</u> , <u>G. x texana</u> , <u>G. triacanthos</u>
Unknown	<u>G. microphylla</u>

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RESISTANCE OF PIN OAK TO IRON CHLOROSIS:
A TECHNIQUE FOR DETECTING GENETIC VARIATION¹

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INTRODUCTION

A much-criticized aspect of the "Green Revolution" breeding programs sponsored by the Rockefeller Foundation is that they have emphasized too strongly the improvement of crop plants for use only with intensive fertilization. The criticism may or may not be justified in terms of the particular goals of this most famous of plant breeding endeavors. But it is becoming increasingly obvious that geneticists have paid too little attention to traits that confer adaptation to the edaphic environment. In the words of one proponent of the subject (Foy 1975), "Crop varieties have been directly selected for practically everything except adaptation to the soil, the most basic resource of all." Opportunities for breeding plants for resistance to mineral deficiencies or excesses in the soil have not been widely perceived, let alone explored in actual breeding programs (Epstein 1972). It has been too easy and inexpensive to modify the soil (usually with fertilizers) to fit the plant, rather than genetically modify the plant to fit the soil.

This situation is changing, however, with the increasing cost of fertilizers. Furthermore, it has never been the case with some low-value crops and some soils in which conditions differ radically from the optimum. According to Foy (1975) some soil fertility situations in which the genetic approach looks promising are: acid soils with soluble aluminum in toxic concentrations, soils polluted with heavy metals, and calcareous soils with unavailable iron. There is ample evidence that plant species can contain substantial genetic variation in adaptation to soil conditions (Epstein 1972, Foy 1975). Reports cited by these authors concern agronomic crops and some non-crop species, but some studies have dealt with forest trees. In some instances, intraspecific variation in actual performance on different kinds of soil has been

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found (Jenkinson 1974, Teich and Holst 1974). In others, leaf tissue analyses have shown clones or provenances to differ in the accumulation of certain nutrients (Baker and Randall 1974, Gerhold 1959, Steinbeck 1965). When, as in the cases cited, trees differ in the accumulation of some nutrients but not others, there is good reason to believe that the differences are due to genetically controlled mechanisms of mineral absorption or distribution (Epstein 1972).

In light of this, we considered the possibility of selecting within pin oak (Quercus palustris) for resistance to iron-deficiency chlorosis. In spite of the fact that the number of pin oaks sold in the United States surpasses the number of all other oak species combined (Flemer 1971), pin oak is often avoided because of its tendency to develop chlorosis on calcareous soils. On such soils, iron in an available form is frequently not present in the concentration needed by plants. Chlorosis in pin oak is characterized by smaller leaves and a yellowing of the leaves between veins. In severe cases, chlorosis causes stunted growth, necrosis and abscission of leaves, twig and branch dieback, and even death of the tree (Neely 1976). Various methods of soil modification and trunk implantation of iron have been used to correct the symptoms (Hacskaylo and Struthers 1959, Neely 1973 and 1976, Schoeneweiss 1973, Smith 1973), but the treatments are expensive and only temporarily effective. A cultivar resistant to iron chlorosis would remove a major objection to planting pin oak and reduce costs associated with its maintenance and replacement. Such cultivars have been developed in some agronomic crops and fruit and nut species (Brown 1961, Foy 1975, Wallace and Lunt 1960), and there is some evidence that sweetgum (Liquidambar styraciflua) varies in susceptibility to iron chlorosis (Wallace and Lunt 1960).

In this report we present the results of an experiment to determine an appropriate nutrient solution technique for screening seedlings for resistance to chlorosis. Hydroponics was selected as a basis for the technique because it affords the possibility of space-efficient, early screening of progeny for actual testing on calcareous soils, and because it enables one to control all aspects of the root environment. Many edaphic factors besides iron concentration may influence the development of chlorosis (Brown 1956, Brown 1961, Neely and Schoeneweiss 1974, Wallace and Lunt 1960), and the uncontrolled effects of these variables in one or a few field tests could hamper the selection of a clone of general, rather than specific, utility. Furthermore, sequentially growing a seedling in two entirely different environments is one means of replication and could enable

the detection of individual tree differences in susceptibility without cloning. This is especially true of a trait like chlorosis, which may be "turned off" by correction of the iron deficiency to eliminate carry-over effects from one environment to the next.

MATERIALS AND METHODS

Pin oak seeds were collected in fall 1975 from 5 local street trees, bulked into one seedlot, and stratified. In spring 1976 the seeds were germinated in a mixture of peat, perlite, and soil. After germination the seedling shoots were cut back once in the germination flat to control size and insure that most shoot growth would occur after the treatments had begun. Root systems were washed thoroughly upon transfer to the nutrient solution treatments. At that time, regrowth of the shoots had not yet occurred, so cotyledons were temporarily left attached to the plants until leaves could supply photosynthate.

The apparatus for the hydroponics system consisted of 18 glass jars, each containing 900 ml. of nutrient solution supplied with air forced through microtubules. Jars were capped with styrofoam plugs containing slits for supporting the seedlings and were covered with aluminum foil to prevent heat accumulation and algal growth. A mechanism was devised to maintain water levels in the containers as transpiration occurred, but transpiration was not great enough to warrant its use.

On April 30, two seedlings were transferred to each container, and each pair of seedlings was given one of the following treatments in the stock solution shown in Table 1:

<u>Treatment number</u>	Iron concentration (p.p.m.)	<u>pH</u>
1	0.1	6.0
2	0.1	7.0
3	1.0	6.0
4	1.0	7.0
5	10.0	6.0
6	10.0	7.0

Iron was supplied in the form of an EDTA chelate and pH was adjusted with HCl or KOH. The experiment was set up on a greenhouse bench in a completely randomized design with 3 replications. No supplementary lighting was given. After April 30, pH's of the solutions were read and adjusted every 7 days, and the solutions were replaced every 14 days for the duration of the treatments.

After 10 weeks the treatments were terminated and the seedlings harvested for measurement. By that time most seedlings had made two, and in some cases, three, flushes of growth. Since chlorosis tended to become progressively more severe as the seedlings grew, we measured that trait on only the last set of leaves of those seedlings that had more than one growth flush. There were enough seedlings in this category to give us container averages for all treatment-replicate combinations except one in which both seedlings had died. Chlorosis was rated in two ways: visually scoring the seedlings on a 7-point scale and determining actual chlorophyll content of the leaves. To obtain the latter measurement, we extracted the chlorophyll from two 1.3 mm. leaf disks per jar in boiling 80% ethanol, cooled the solutions to room temperature, brought each to 10 ml. of volume, and read optical density on a Beckman-B spectrophotometer. We also measured shoot height above the cotyledonary node and length and oven-dry weight of the root system below the cotyledonary node.

RESULTS

According to both measures of chlorosis, visual scoring and chlorophyll content, iron concentration had a significant effect on the development of chlorosis (Table 2,3). Particularly when measured by chlorophyll content of the foliage, chlorosis declined as iron concentration in the solution increased, but the effect of raising iron from 0.1 to 1.0 p.p.m. was much greater than the effect of raising it from 1.0 to 10.0 p.p.m. The effect of pH treatment, on the other hand, was significant only when chlorosis was visually rated--chlorosis was greater at the higher pH. In both cases the variance component for iron treatment was much larger than that for pH treatment (Table 4). Iron x pH interaction was not significant with either variable.

Shoot height was significantly affected by both iron and pH treatments. The lowest iron concentration resulted in seedlings that were shorter than those in either of the two other treatments, and seedlings were shorter when grown in solutions adjusted to the higher pH. Again, the effect of iron treatment on variation in height growth was greater than that of pH treatment, and iron x pH interaction was not significant.

Neither root length nor weight was significantly affected by iron or pH treatments. However, this result contrasts with the fact that we observed obvious differences in root development associated with iron concentrations. Plants grown at progressively higher concentrations had darker

(almost black at 10.0 p.p.m.) and more fibrous root systems. The pronounced proliferation of very small roots, particularly at 10.0 p.p.m. iron, presumably had little effect on the total weight of the roots. In addition, there were apparently physiological differences in effect on the edaphic environment among the root systems grown at different iron concentrations. When pH of the solutions at 7 days after adjustment was averaged for the duration of the experiment, it was found that those adjusted to 6.0 had tended to rise to 6.3 and those adjusted to 7.0 to fall to 6.7. However, the change at the two lower concentrations of iron was significantly greater than the change at the higher concentration.

DISCUSSION

The effect of decreasing iron concentration on chlorosis development was, of course, expected. However, it is somewhat surprising that some chlorosis was observed at 1.0 and even 10.0 p.p.m. iron (Table 2). According to Lindsay (1974), most crops require less than 0.5 p.p.m. iron. A commonly used modification of Hoagland's solution (Epstein 1972) only provides 1.12 p.p.m., and most nutrient solutions are formulated to provide nutrients in higher concentrations than are needed by most plants. Carpenter (1952) also observed chlorosis in pin oak growing in a solution containing 1 p.p.m. iron at pH 7.0. Hence, pin oak may require more iron than other plants, regardless of pH or the presence of calcareous soil. If this is true, it removes some potential sources of genotype x environment interaction in genetic studies on this trait in pin oak. The parallel variation between lack of chlorosis and shoot height ($r = + .80$, with 15 d.f.) is as expected since chlorosis impairs the production of photosynthate.

High soil pH on calcareous sites is frequently associated in the literature with chlorosis in pin oak (Neely 1973, Neely and Schoeneweiss 1974, Smith 1973). The critical pH is usually assumed to be 6.7-7.0. The effect of pH is to change the solubility of ions and the relative concentrations of specific ionic forms--and plant absorption depends on ionic form as well as concentration (Moore 1974). In the case of iron, the effect of increasing pH is to increase the oxidation of ferrous to the much less soluble ferric ionic form, and to decrease the solubility of both forms (Lindsay 1974, Wallace and Lunt 1960). These effects of pH are counteracted, however, when iron is supplied as a chelate, the extent of counteraction depending on the particular chelate used (Lindsay 1974).

This may explain the fact that pH treatment had a smaller effect on chlorosis than iron treatment in this experiment in which Fe-EDTA was used as the iron source. Schoeneweiss

(1963) observed only slight chlorosis on pin oak at pH 7.0 when iron was supplied to the nutrient solution in chelated form, but severe chlorosis at the same pH when the iron source was FeSO_4 . Similarly, Carpenter (1952) observed "acute" chlorosis on pin oak growing in a solution containing 1 p.p.m. iron at pH 7.0 while we observed only slight chlorosis for the same treatment. Though the source of iron was not stated for that study, its date indicates that a chelate probably was not used. If so, this would explain the discrepancy between our results.

Schoeneweiss and Carpenter used treatments of pH 5.0 and 7.0, and both found differences in chlorosis development between the two levels. Our results for pH were inconsistent -- one measurement method showed a significant effect of pH on chlorosis and the other showed virtually no effect. However, considering the fact that pH treatment had less effect than iron treatment on chlorosis when measured by both methods, it appears that resistance to chlorosis could be effectively screened by monitoring only an appropriate iron concentration, one in the range of 0.1 to 1.0 p.p.m., and letting pH stabilize. This conclusion is strengthened by the fact that the pin oak roots tended to change pH of the solutions toward the midpoint of the pH 6.0-7.0 range used in the experiment.

It is surprising that we found a significant effect of pH on chlorosis when measured by the visual scoring system, but not when measured by the presumably more accurate method of chlorophyll content. However, more weight should be placed on the former result, especially since shoot growth was also significantly affected by pH. On the other hand, measuring chlorophyll content was the more useful method at the two higher iron (and chlorophyll) levels, where the visual method was apparently inadequate for detecting real differences (Table 2).

The significantly greater buffering effect on nutrient solution pH of the plants growing at low iron concentrations is similar to one of the known mechanisms of chlorosis resistance. Though the difference was not significant, the effect was slightly greater at pH 7.0 than at pH 6.0, particularly at the two lower iron concentrations and in the later weeks of the experiment when the root systems were larger. It is well known that roots can bring about significant changes in the pH of the root environment, and these changes in pH can have profound effects on the roots themselves (Moore 1974). Foy (1975) has observed that the ability of plants to alter soil chemical properties within the microzones of their roots may be one trait complex that is susceptible of genetic manipulation. He has found,

for example, that one iron-efficient strain of weeping love-grass that does not develop chlorosis in low-iron nutrient solutions also maintains a lower pH in solution than does a strain susceptible to chlorosis.

There remains the question of whether any pin oaks selected for resistance to chlorosis with this method would also manifest resistance in field tests. An affirmative answer is supported by two observations. The first is that a closely related species, red oak (Quercus rubra), does not develop chlorosis in some situations in which pin oak does, and this is true either in the field or in nutrient solutions in which iron source and pH are varied (Schoeneweiss 1963). If some pin oaks have a similar mechanism of resistance, they could be effectively selected in a hydroponics system. The second concerns a series of studies reviewed by Brown (1961) on chlorosis-susceptibility in two varieties of soybean. One variety develops chlorosis when grown on three kinds of calcareous soil, and it is also chlorotic when grown in nutrient solutions containing less than 5 p.p.m. iron. The other does not develop chlorosis on any of the three soils, and it does not become chlorotic in solutions containing as little as 2 p.p.m. iron.

SUMMARY

Nutrient culture techniques would be effective in screening for efficiency of iron utilization in pin oak, and the results would probably be applicable to the problem of iron chlorosis on calcareous soils. The method outlined here could be expanded to aggregate culture (where roots provide support as well as nutrient absorption) in large containers for use in screening large numbers of seedlings. Such a technique, as opposed to testing on calcareous soil, would be space-and time-efficient and would insure that selection is for response to only one environmental variable. Chlorosis in response to variables other than iron concentration would be eliminated as a possibility. In addition, if the seedlings were later outplanted to a calcareous site, the replication obtained would permit measurement of individual tree genetic variation without cloning. The possibilities of obtaining genetic superiority in chlorosis-resistance in this species are unknown, but we may be encouraged by the successes achieved in other species.

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TABLE 1.--Composition (excluding iron) of nutrient solutions used in treatments.

Source	Concentration	Element	Concentration
	grams/liter		p.p.m.
KNO ₃	5.055 ^a	N	210.2
Ca(NO ₃) ₂ ·4H ₂ O	11.808 ^a	P	31.0
KH ₂ PO ₄	1.361 ^a	K	234.6
MgSO ₄ ·7H ₂ O	4.930 ^a	Ca	200.4
H ₃ BO ₃	7.173 ^b	Mg	48.6
CuSO ₄ ·5H ₂ O	0.200 ^b	S	64.1
MnCl ₂ ·4H ₂ O	4.511 ^b	B	0.125
ZnSO ₄ ·7H ₂ O	0.601 ^b	Cu	0.005
Na ₂ MoO ₄ ·2H ₂ O	0.110 ^b	Mn	0.125
		Cl	0.162
		Zn	0.014
		Mo	0.004

^a_x 10⁻¹

^b_x 10⁻⁴

TABLE 2. Average chlorosis score, index of chlorophyll content, and shoot height for three iron and two pH treatments.

Treatment	Chlorosis score	Index of chlorophyll content ^a	Shoot height
1=extreme 7=none			
(ppm)		<u>Iron</u>	
0.1	1.50	8.53	12.05
1.0	4.33	16.57	18.83
10.0	<u>4.58</u>	<u>21.62</u>	<u>18.83</u>
Least Significant Difference: ^b	1.32	3.72	2.38
<u>pH</u>			
6.0	4.06	15.61	19.29
7.0	<u>2.89</u>	<u>15.53</u>	<u>13.86</u>
Least Significant Difference: ^b	1.08	3.04	1.94

^aOptical Density Units on a Beckman-B spectrophotometer x 10; low values = low chlorophyll content.

^b5% level of significance.

TABLE 3.--Analyses of variance for chlorosis score, index of chlorophyll content, and shoot height.

Source of variation	Degrees of freedom	Chlorosis score	Index of chlorophyll content	Shoot height
----- (mean squares) -----				
Fe	2	17.597***	261.211***	92.027***
pH	1	6.125*	0.027 ns	132.845***
Fe X pH	2	0.042 ns	16.734 ns	12.172 ns
Error	11	1.076	8.566	3.512

ns = Not significant

* = Significant at the 5% level

*** = Significant at the 0.1% level

TABLE 4.--Variance components for chlorosis score, index of chlorophyll content, and shoot height.

Source of variation	Chlorosis score	Index of chlorophyll content	Shoot height
Fe	5.5071	84.2150	29.5050
pH	0.5610	0	14.3703
Fe X pH	0	5.4456	5.7731
Error	1.0758	8.5655	3.5121

SELECTING TREES FOR THEIR RESPONSE TO WOUNDING¹

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This will not be a report on a single study - rather it will be a preliminary report on a series of investigations we have begun on a number of species of trees in several parts of the country. Detailed information will be published in a series of technical reports later, but I do want to tell you about the methods we are using and what the results of these investigations might mean to you.

While we didn't bother to locate recent figures that we could quote to you, I suspect the cost of replacing trees in residential areas and on city streets runs into many thousands of dollars annually. A few of these trees might actually be dying of old age as suggested by Tom Perry, but many of them are going prematurely because they are badly decayed - and decay usually starts with wounds of one form or another.

The thought that all of those trees need to be replaced may appeal to some nurserymen, but it probably has the opposite effect on urban and municipal foresters - or at least the people who control the purse strings and the taxpayer. The ideal tree from their point of view would be one that you could run cars into, carve initials on, and generally abuse - and have the tree seal off the injury and continue to grow normally.

Finding injured trees in any major city is not a problem, as Ruth Foster has shown us, but many of these are of seed origin. If they have been vegetatively propagated, the clonal identification has long since been lost. It is impossible to do much with this type of material except to say that certain species are able to survive the collective abuses encountered in cities.

We became interested and involved in the problem of wound response when an older stand of hybrid poplar was cut for a lumber grade study. It was obvious in looking at the ends of logs stacked at the sawmill that large differences in the diameter of discoloration columns were present. Fortunately,

¹ Metro. Tree Impr. Alliance (METRIA) Proc. 1: 69-72, 1978.

we had recorded clone numbers on each log and with some quick measurements, we were able to show that the variation was between clones and not between trees (Garrett, Shigo, and Carter 1976).

Discoloration between clones ranged from 56% to 85% of the total stem diameter. Only six clones were involved in this operation and the clones were of mixed parentage. The exact cause of discoloration was not determined and the time of wounding which apparently is an important factor could not be determined. Wounding by our definition includes everything from bulldozer blades to natural pruning of branches. With all of these unknowns, we decided to try a more systematic approach and see what happened.

Most studies of wound healing in trees have concentrated on callous formation and wound closure. Wound closure was almost synonymous with wound healing. Wound healing is more than that. Large wounds may never completely close, but they may heal - from the inside. It appears that we are working with at least two internal defense mechanisms in trees. First there are the chemical barriers that keep out most wood-destroying microorganisms and to combat those organisms that get by the first line defenses, trees have evolved a system for walling off or confining the area of infection. Our next study confirmed just how effective the second defense mechanism is in some trees.

The only genetically uniform material in our area of a size suitable for wounding was another planting of hybrid poplar. We took brace-and-bit in hand and attacked. Sixty trees representing 9 different clones of Populus deltoides Marsh x P. trichocarpa Hook. were wounded. The program was complicated just a bit by the number of wounds inflicted (14), height of wounds (4) and time of year (3). The wounds were all 1.5 cm in diameter and 5 cm deep.

Closure of wounds was measured in July and the results were exactly what we were expecting. Trees in some clones had open wounds while wounds in other clones were completely closed. In October the trees were cut and dissected to record internal discoloration patterns. The ability of some clones to isolate infected tissue was striking while trees in other clones developed large columns of discolored wood. Again, the degree of column formation among clones was significantly different (Shigo, Shortle, and Garrett 1976).

The results of this study suggested that wound healing - closure and isolation of infected tissue - might be under genetic control. If this is in fact the case, then effective selection for resistance to wound diseases, a major cause of damage to trees, would be a distinct possibility.

The next phase of this research was to try to determine the heritability of closure and compartmentalization. To find trees large enough we went to Mississippi. Cooperating with the Genetics Project of the Southern Station we wounded fifty-nine clones of P. deltoides to confirm our earlier work and because they were available in a replicated test. The important part of the southern work involves 81 families of sweetgum (Liquidambar styraciflua L.). Wound closure was measured in mid-June and indications are that there is a strong clonal response. Trees will be cut in early October and dissected to measure internal compartmentalization.

A follow-up study in black walnut (Juglans nigra L.) half-sib families will be made next spring and evaluated in the fall. The tree breeding project at Carbondale, Illinois will provide the material and cooperate with us on this study. When the walnut response has been evaluated, we will review the overall project. If all three species have responded in a similar manner - and we expect they may - then we will be in a position to recommend action programs. If we do find individuals that are capable of responding to wounding in a positive way, it will be necessary to maintain these trees in a healthy condition for breeding purposes or as sources of scion material for rooting or grafting programs. Until recently, it has been necessary to cut the tree to examine and evaluate internal wound response (i.e., compartmentalization of infected tissue). The Shigometer which requires only a very small hole (3/32" diameter) in the tree trunk near the wound may be a solution to this problem.

I am certain that the first nursery on the market with trees guaranteed to resist some of the damages associated with wound will find a large and ready market in urban and municipal forestry programs.

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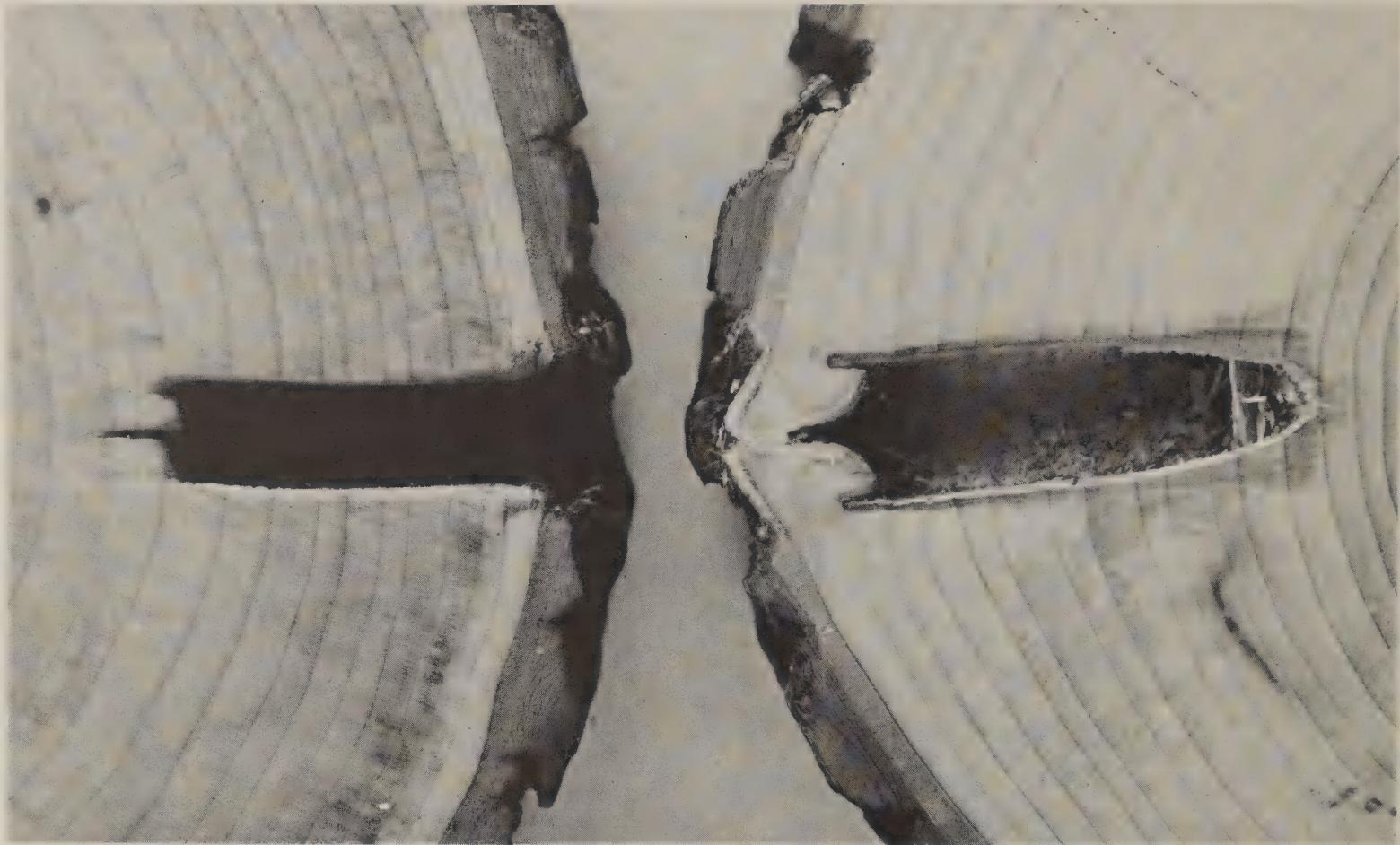


Figure 1. Clone at left showing slow wound closure and poor compartmentalization of discoloration. Clone at right closed rapidly and has practically no discolored wood associated with the wound.

INTERSPECIFIC HYBRIDIZATION IN CARPINUS

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ABSTRACT.-- This paper is a first report on successful interspecific controlled pollination in Carpinus, involving five species. C. tschonoskii was a tetraploid rather than diploid (as previously reported), C. betulus was octoploid, and the other species were diploid. Female parents in all species appeared to be highly self-incompatible. Three authentic interspecific hybrid combinations were produced: C. betulus X orientalis (and reciprocal), C. betulus X tschonoskii and C. orientalis X tschonoskii. The hybrids were verified by chromosome counts on seedling root tips. Metro. Tree Impr. Alliance (METRIA) Proc. 1: 73-79, 1978.

There is a definite need for a wider range of choice in shade and landscape trees of moderate height(30-40 feet) at maturity. Among the trees in this category currently being investigated at the U.S. National Arboretum are the hornbeams of the genus Carpinus. No major insect or disease pests have been reported that might limit the culture of the hornbeams.

Although the genus may include as many as 26 species, (Rehder, 1940), few are in cultivation in the United States. The European hornbeam(C. betulus L.) is extremely popular in Europe, partly because it can withstand repeated clipping for hedges and ultraformal plantings. Although modern American horticultural practice seldom includes "hedging" of trees, many American nurseries offer C. betulus and its cultivar 'Fastigiata'. Wyman (1965) has pointed out that nomenclatural confusion has resulted from trees of both the cultivars 'Fastigiata' and 'Columnaris' being distributed under the name 'Fastigiata'..

The other available species in the genus are superior to European hornbeam in one or more landscape characteristics. A few nurseries grow our native American

hornbeam (C. caroliniana Walt.). This species, as well as C. japonica Bl. and C. tschonoskii Maxim., can develop a desirable vase-shaped form. The Japanese and American hornbeams may also exhibit an attractive orange to russet-red autumnal leaf coloration in some climatic zones. Fall color is less characteristic of the slow-growing C. orientalis Mill., but the delicate foliage texture and interesting growth habit of this species may have merit in certain situations.

Sargent (1896) defined two sections in Carpinus. Of the species investigated here, only C. japonica is classified in Sect. Distegocarpus. The rest of the species belong to Sect. Eucarpinus (= Sect. Carpinus).

Wetzel (1929) studied pollen-mother-cell meiosis in C. betulus and reported $n=8$ chromosomes. This count was confirmed by Jaretsky (1930). Woodworth (1930) likewise found $n=8$ in a "normal" tree of this species but reported $n=32$, an octoploid number, in C. betulus var. fastigiata Jaeg. (=cv. Fastigiata). Scheerer (1940) reported $n=32$ for native trees in Schleswig-Holstein and Sylven, by personal communication to Scheerer (1940), found $n=32$ in trees of Swedish origin. Johnsson (1942) investigated native trees from seven locations in Sweden and found all to be octoploid with $n=32$ chromosomes. He also studied meiosis in a botanic garden specimen of C. carpinizza Kitaibel ex Host and found it to be a diploid with $n=8$ chromosomes. The significance of this finding is that C. carpinizza was accepted by Rehder (1940) as C. betulus var. carpinizza (Host) Neilreich. Thus, C. betulus was believed to occur in both diploid and octoploid forms, and some authors thought that "races" with intermediate numbers might exist.

For the other species used in our hybridization studies, Woodworth (1930) reported $n=8$ for C. caroliniana, C. japonica, and C. orientalis. Johnsson (1942) studied a botanic garden specimen of C. tschonoskii and found it to be a diploid with $n=8$ chromosomes.

To our knowledge, no natural or artificial inter-specific hybrids have been reported in Carpinus. The purpose of the present study was to determine the crossabilities of several Carpinus species and to investigate the chromosome number of parents and progenies.

MATERIALS AND METHODS

All of the trees in this study were growing at the U. S. National Arboretum or the Plant Introduction Station at Glenn Dale, Maryland. No more than two trees of any species were available for crossing. The male catkins were the first to mature on all species. These catkins were removed from selected branches before anthesis, and the female catkins were enclosed in a terylene non-woven fabric bag. about two to three days after normal pollen shedding on each tree, we pollinated the female flowers by carefully removing the bag and applying pollen with a pipe cleaner. The bags were replaced after pollination and left on the branches for another two weeks.

Fruit catkins were harvested in late August, when the bracts had begun to turn brown. The seeds were removed manually from the bracts, and the numbers of seeds and bracts were counted. After about a week, most of the seeds had lost any green color. Seed from crosses on C. betulus and C. orientalis were immersed in a 2% solution of ethyl alcohol to distinguish full seed ("sinkers") from empty seed ("floaters"). The full seed were then stratified in moist sand in a refrigerator for 120 days before sowing. Seed harvested from C. japonica could not be separated by the flotation test. Therefore, all seeds were stratified. An estimate of the percentage of good seed from the intraspecific C. japonica cross was made by a cutting test on a 50-seed random sample.

All of the seed from crosses on C. betulus and C. orientalis and about 80 of the intraspecific C. japonica seed were row-planted in greenhouse flats in January. The remainder of the seed from C. japonica was broadcast-sown. Germination of many of the seedlots from crosses on C. betulus in 1974 was poor or non-existent after 11 weeks. The ungerminated seed was dug up and re-stratified for 100 days and resown in July. All the seedlings that developed from this double-stratified seed (C. betulus X Self, C. betulus X betulus 'Cordata', C. betulus X orientalis) germinated within one week after the second sowing.

Cytological studies of meiosis were made on male catkins brought into the laboratory for forcing in February. Mitotic chromosome counts were made on root tips of seedlings derived from open or controlled pollination. Standard acetocarmine squash techniques were employed for all cytological work. Measurements of mature pollen grains were based on 50 randomly selected grains, and pollen abortion was determined from examination of 100 random grains.

RESULTS AND DISCUSSION

Cytology and pollen.-- Table 1 gives the chromosome numbers of the parent trees used in hybridization. One important finding was that our C. tschonoskii trees were tetraploids, with $n=16$, $2n=32$ chromosomes, rather than diploids. All individuals of C. betulus were octoploids. Polyploids could be easily distinguished from diploids by pollen size, but there were no significant differences between tetraploids and octoploids. The number of germinal apertures in the pollen grain was 3 for diploid species, 4 for C. tschonoskii, and 4 to 5 for C. betulus. Pollen from all trees showed less than 5% abortion.

We were fortunate in having seedlings of C. betulus and C. orientalis from several known provenances in Yugoslavia. Yugoslavia is in the southern portion of the range of C. betulus, and the fact that the trees were octoploid casts some doubt on the idea of geographic cytological races in this species. I submit that C. betulus may be entirely octoploid and that an intensive cyto-taxonomic study of European Carpinus species might lead to the verification of one or more "new" species.

The differences in chromosome number among parental species allowed a simple verification of the interspecific hybrid seedlings.

Controlled pollination.-- Table 2 gives the results of controlled pollinations. Pollen origin appeared to have little effect on the percentage of female catkins that matured to interspecific pollinations, with an overall average of 79 percent. Only two interspecific combinations-- C. betulus X japonica (32%) and C. japonica X orientalis (51%) -- were significantly below this average.

The seeds (nutlets) produced in the female catkins were subtended by a large bract, and a count of the bracts indicated the potential number of seeds that could be developed. For the three species used as female parents, the bract numbers were: C. betulus, 13.9; C. japonica, 34.7; C. orientalis, 8.9.

Based on present evidence, Carpinus species appear to be highly self-incompatible. This characteristic could be an advantage to the breeder when dealing with isolated trees. We tried pollinating, without bagging, an isolated tree of C. betulus with C. tschonoskii pollen. The results indicated that such a technique could be very successful.

C. japonica, used as both the male and female parent, did not produce hybrids with any other species. The taxonomic classification of C. japonica in a different section than the other species thus appears reasonable on a genetic basis.

Only three authentic interspecific hybrid combinations were produced: C. betulus X orientalis (and reciprocal), C. betulus X tschonoskii, and C. orientalis X tschonoskii. Fortunately, the three parental species differed in chromosome number and the hybrids could be verified cytologically. We did not attempt to establish morphological criteria of hybridity on the young seedlings.

The germination data in Table 2 show that more reliable methods must be found to assay seed development, determine seed germination potential, and produce good yields of control-pollinated seedlings. Without efficient seed evaluation and germination techniques, some "successful" crosses may be missed, and progeny numbers in certain seedlots may be too few for meaningful evaluation and future selection.

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Table 1. Chromosome and pollen data on Carpinus parents, hybrid progeny, and provenance seedlings.

Species or Cross	Chromosome Number	Pollen Size (microns)
<u>Parents</u>		
C. <u>caroliniana</u>	n=8, 2n=16	30.2
C. <u>japonica</u>	n=8, 2n=16	27.9
C. <u>orientalis</u>	n=8	28.4
C. <u>tschonoskii</u>	n=16, 2n=32	36.3
C. <u>betulus</u>	n=32, 2n=64	38.9
C. <u>betulus</u> 'Cordata'	n=32	39.6
C. <u>betulus</u> 'Purpurea'	n=32	36.7
<u>Provenance Seedlings (Yugoslavia)</u>		
C. <u>orientalis</u>	2n=16	—
C. <u>betulus</u>	2n=64	—
<u>Hybrid Seedlings</u>		
C. <u>betulus</u> X <u>orientalis</u>	2n=40	—
C. <u>orientalis</u> X <u>betulus</u>	2n=40	—
C. <u>betulus</u> X <u>tschonoskii</u>	2n=48	—
C. <u>orientalis</u> X <u>tschonoskii</u>	2n=24	—

Table 2. Results of controlled pollinations in Carpinus, 1973-1974.

Cross ^a	Number Catkins		Potential ^b	Number Seed Harvested	Full	Germinated
	Pollinated	Harvested				
<u>C. japonica</u> <u>X Self</u>	11	11	382	382	?	2
<u>X japonica</u>	24	23	833	810	550 ^c	192
<u>X betulus</u>	12	8	416	332	?	0
<u>X b. 'Purpurea'</u>	36	31	1249	1070	?	2 ^d
<u>X orientalis</u>	43	22	1492	760	?	0
<u>X tschonoskii</u>	20	18	694	571	?	0
<u>C. betulus</u> <u>X Self</u>	15	9	209	34	20	8
<u>X b. 'Cordata'</u>	20	16	278	161	133	17
<u>X b. 'Purpurea'</u>	19	15	264	143	125	0
<u>X caroliniana</u>	18	16	250	129	6	1 ^d
<u>X japonica</u>	31	10	431	9	0	--
<u>X orientalis</u>	29	28	403	336	58	10
<u>X tschonoskii</u>	32	27	445	286	141	38
<u>C. orientalis</u> <u>X Self</u>	11	9	98	23	1	1
<u>X betulus</u>	29	29	258	249	24	18
<u>X japonica</u>	18	18	160	104	0	--
<u>X tschonoskii</u>	12	12	107	102	4	4

^{a/} Female parent listed first.

^{b/} Based on average number of bracts per catkin pollinated.

^{c/} Estimated from cutting tests.

^{d/} Non-hybrid seedlings.

VARIATION IN AIR POLLUTION TOLERANCE AND GROWTH
RATE AMONG PROGENIES OF SOUTHERN APPALACHIAN WHITE PINE

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ABSTRACT.--Two-year-old open-pollinated progenies from 13 pinus strobus stands in Georgia, North Carolina and Tennessee were planted in three different physiographic regions of Tennessee. About 30,000 progenies, representing 129 families, were evaluated after five growing seasons in the field. Variation in growth rate of trees from different stands were highly significant. Progenies from the three Cumberland Mountain stands consistently grew fastest in the three test locations. Also, these progenies had darker green and longer needles than progenies from the other stands, indicating greater resistance to SO₂-damage from nearby coal-burning steam plants. Within most stands there were mother trees which produced progeny that grew significantly faster and had longer, darker green needles than progeny from other mother trees in the same stand. Estimates of narrow-sense heritability for height growth varied from 0.20 to 0.33. By selecting the best individual progenies from the best families in the best stands estimated gains in juvenile height growth varied from a minimum of 20 percent to a maximum of 73 percent. Metro. Tree Impr. Alliance (METRIA) Proc. 1: 80-86, 1978.

INTRODUCTION

Several studies indicate that eastern white pine (Pinus strobus L.) from the Southern Appalachians may outgrow trees of local origin in both the Northeast and Midwest (Funk 1965; King and Nienstaedt 1969; Garrett *et al.* 1973). Seed-source tests in southern locations indicate a clinal variation pattern associated with source latitude (Genys 1968; Sluder and Dorman 1971; Thor 1974). The gradual reduction in progeny growth with increasing latitude of the source does not preclude locally adapted ecotypes. That such ecotypes do indeed exist at the southern limit of the species range is suggested by the large amount of variation in progeny height of sources from between latitude 35° and 36° North (Thor 1974).

In addition to the observed geographic variation patterns there is experimental evidence for genetic differences among individual white pines for both sulfur-dioxide tolerance and growth rate. Broad-sense heritability estimates for sulfur-dioxide tolerance tend to be high (Houston and Stairs 1973) while narrow-sense heritability estimates for juvenile height growth are low (Kriebel *et al.* 1972; Thor 1974).

The wide variation in height growth of trees from different stands in the extreme southern end of the species range suggested that more intensive sampling from this part of the white pine range would be necessary to capitalize on the apparent ecotypic variation. Also, estimates of variation among trees and narrow-sense heritability estimates for air pollution tolerance and growth rate would be valuable in eastern white pine breeding programs. One such study was established in 1970 with open-pollinated progenies from 13 stands in Georgia, North Carolina, and Tennessee. Two-year-old seedlings representing 129 open-pollinated families were planted in four physiographic regions of Tennessee. Five-year height measurements were obtained from about 30,000 progenies in three of these plantations.

HEIGHT GROWTH

Differences in growth rate of trees from different stands in the Southern Appalachians were highly significant. Trees from stands in three East Tennessee counties (Anderson, Morgan, and Scott) consistently grew fastest in the three test locations (Table 1). On the Highland Rim, progenies from these three stands grew 25 percent faster than progenies from the three North Carolina stands. However, these differences in growth between North Carolina and local sources were small compared to differences observed at the Cumberland Mountain test site; at this location trees from local stands (Anderson, Morgan, and Scott Counties) had a height superiority of 53 percent over those from North Carolina. Differences of this magnitude indicate that in addition to the north-south clinal variation pattern there has been considerable ecotypic differentiation in the extreme southern part of the species range.

TABLE 1. Mean height (in feet) of white pine progenies from 13 stands after five growing seasons in three locations.

County	State	Location of Test Plantations		
		Great Valley	Cumberland Mt.	Highland Rim
Monroe	TN	4.44	5.68	5.47
Polk	TN	4.71	6.65	5.74
Fanin	GA	4.74	5.81	5.72
Cherokee	NC	3.92	4.66	4.86
Madison	NC	4.69	5.07	5.52
Cocke	TN	4.51	5.80	5.52
Unicoi	TN	4.83	6.29	5.82
Unicoi	TN	4.80	6.20	5.78
Transylvania	NC	3.59	4.27	4.63
Carter	NC	4.10	5.16	4.71
Scott	TN	4.81	6.75	6.02
Morgan	TN	5.14	7.34	6.29
Anderson	TN	5.63	7.36	6.52
		4.72	6.05	5.63

Ten to 15 percent of the total variation in height observed in individual plant tions was accounted for by stands (source of seed). An additional 5 to 7 percent of height variation was contributed by differences among half-sib families. Within most stands there were families that grew significantly faster than other families (Figure 1). This variation among families within stands is reflected in the estimates of narrow-sense heritability, varying from 0.20 to 0.33. By selecting the best individual progenies from the best families it is possible to make gains of about 20 percent in juvenile height growth. Such gains may, of course, be added to any gains realized by using seed from the best stands. Thus, the gain in mean juvenile height growth from one generation of selection will be about 20 percent above the mean height of unselected progeny from the best seed sources. The maximum gain will be between 45 and 73 percent above the height of progeny from the poorest Southern Appalachian sources.

AIR POLLUTION TOLERANCE

Several coal-fired steam plants in East Tennessee emit large amounts of sulfur dioxide and have been held responsible for the killing or damaging of forest stands and Christmas tree plantations. In stands destroyed by high levels of sulfur dioxide, individual trees with no apparent damage have been observed. That this resistance is genetically controlled has been confirmed in clonal tests. Since white pines for most uses are propagated by seed (sexually) rather than by cloning (asexually) it is desirable to determine the narrow-sense heritability for resistance to sulfur dioxide damage. One progeny test in the fall-out area of the Bull Run Steam Plant in the Great Valley is giving this information.

Two continuous sulfur dioxide monitoring stations, both located about one mile from the progeny test plantation near Bull Run Steam Plant, recorded hourly averages for April, May, and June 1974. During this period hourly averages ranged from less than 1 to 10 parts per hundred million (pphm). A great number of progenies from some of the 90 open-pollinated families represented in this plantation showed symptoms of air pollution damage (yellow, short needles and/or tip burn) when evaluated in December 1974. Even though it was not possible to distinguish between needle damage from ozone and sulfur dioxide there is no evidence that ozone levels sufficiently high to produce needle damage were present in the area. On the other hand, the recorded levels of SO_2 were ample to cause the observed symptoms; Costonis (1973) found that exposures of SO_2 -sensitive eastern white pine ramets to sulfur dioxide at a concentration of 5 pphm for 2 hours was sufficient to induce necrosis of new needles.

In this plantation the progenies from stands in Anderson, Morgan, and Scott counties, originating from the airsheds of two steam plants, had longer, darker-green needles than progenies from other stands in the Southern Appalachians (Table 2). Also, trees from Polk and Monroe counties in Tennessee and Fannin County in Georgia had a high "needle index" indicating that the proximity of these stands to the Cooperhill smelting operations has resulted in removal of the most susceptible genotypes from these populations.

Table 2. Thirteen white pine stands ranked according to needle color and needle length of progenies growing near Bull Run steam plant in the Great Valley.

Stand No.	Stand Location	Color ^{a)} Score	Needle Length cm.	Needle ^{c)} Index
13	Anderson Co., Tenn.	3.07	7.52	3.28
11	Scott Co., Tenn.	3.03	7.50	3.22
2	Polk Co., Tenn.	3.00	7.31	3.00
3	Fannin Co., Ga.	2.94	7.00	2.63
12	Morgan Co., Tenn.	2.85	7.81	3.35
1	Monroe Co., Tenn.	2.73	7.18	2.60
8	Unicoi Co., Tenn.	2.70	7.08	2.47
5	Madison Co., N.C.	2.64	7.07	2.40
4	Cherokee Co., N.C.	2.52	6.81	2.02
10	Carter Co., Tenn.	2.36	7.32	2.36
7	Unicoi Co., Tenn.	2.30	7.13	2.11
6	Cocke Co., Tenn.	2.22	7.00	1.91
9	Transylvania Co., N.C.	1.62	5.69	0.00

a) Each tree was rated 1 for greenish-yellow, 2 for yellow-green, 3 for bluish-green, and 4 for greenish-blue.

b) Vertical lines connect sources not significantly (5 percent level) different in color rating according to the new Duncans multiple range test.

c) Combined value for needle color and needle length.

The variable needle length is a metric character. However, needle colors were obtained by visual ratings and assumed only four discrete values. Inspection of frequency distributions of both these variables suggested that they were normally distributed. The analysis of variance indicated that the variation due to families within stands was significant for both variables while only the stand component was significant for needle color. Variance components for the two needle characteristics are presented in Table 3.

Table 3. Components of variance (in percent) for needle color and needle length.

Variance Component	Needle Color	Needle Length
Replication	7	7
Stand	7	2
Family Within Stand	14	7
Replication X Stand	0	1
Replication X Family Within Stand	72	83
Total	100	100

Since the needle data were obtained as plot means no estimate of within-plot variance was available and the resulting heritability estimates, $h^2 = 0.64$ for needle color and $h^2 = 0.32$ for needle length, must be considered as upper limits.

Cross-products analyses, based on plot means, were performed among the variables needle color, needle length and total height at five years. Highly significant positive correlation coefficients were obtained at both the stand level and family within stand level. When the narrow-sense heritability estimates for needle traits and total height are considered with the correlation among these characteristics it appears that advances in breeding for resistance to sulfur dioxide damage may be attained. Selection may be made in test plantations which are exposed to high levels of sulphur dioxide; the best individual trees from the best families within the best stands may be selected based on either total height or needle characteristics or a combination of both.

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ASH DIEBACK IN THE NORTHEAST: REPORT ON SEVERITY AND CAUSES

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ABSTRACT.--Ash dieback is a disease which causes progressive death of branches and tree mortality in white and green ash (Fraxinus americana L., F. pennsylvanica Marsh.). It affects all-aged trees in woodland, hedge-row, streetside, and home sites. Above-average tree mortality occurred in several northeastern states in the late 1950's and early 1960's. Recent surveys in New York show that the disease generally has become static, except in the southeastern Hudson Valley region, where, for unknown reasons, ash dieback continues to increase in severity. Water stress in the trees and invasion of the bark by canker fungi are the primary causal factors. Air pollution, leaf spotting fungi, viruses, and mycoplasma-like organisms are additional stresses which may be involved in the etiology of ash dieback. Control recommendations are based on the maintenance of high tree vigor. Metro. Tree Impr. Alliance (METRIA) Proc. 1: 87-96, 1978.

INTRODUCTION

Ash dieback is a disease of white and green ash (Fraxinus americana L. F. pennsylvanica Marsh.) Since the late 1950's it has been one of the more important tree problems in the Northeast. Progress has been made in learning the etiology of ash dieback. The apparent complexity of several interacting climatic and biological causal factors, however, suggest that more research is needed before we fully understand this disease.

An unexplained branch dieback was first reported on white ash during 1925-1930 in southeastern Quebec (13) and in several northeastern states of the United States (12). Ash were again reported dying back along roadsides and in hedgerows in southeastern New York in the late 1930's and the 1940's. (Pers. Comm. D. S. Welch, Cornell Univ.) During the 1950's, white ash, and some green ash, were showing abnormal dieback in valuable forest stands (17, 19). Since then, ash dieback

has continued to be a problem in woodlands, hedgerows, home plantings and along roadsides throughout New York, New Jersey, Pennsylvania, and parts of New England (except Maine).

Dieback is a serious problem because ash is widely distributed in the eastern states and is an important component of hardwood forests. The wood has considerable commercial value. Partly because of their rapid growth, white and green ash also have been prominent trees in the nursery trade.

The following report will define ash dieback, describe its severity and known causes, and suggest control measures.

WHAT IS ASH DIEBACK?

The earliest symptoms are reduced radial stem increment, shortened internodal length of twigs, reduced leaf size, and leaves pale green to chlorotic in hue. The foliage sometimes shows premature fall coloration in the form of purplish flecks. Diseased trees often shed their leaves sooner than healthy ones. Reddish brown or orange-yellow, slightly sunken, cankers appear on smooth bark of the main stem and on all sizes of branches.

Figure 1 illustrates some of the dieback symptoms. Branch tips fail to leaf out in the spring and terminal twig dieback commences. The numerous small dead twigs and the clumped foliage on shortened internodes result in a sparse leaf canopy. The stem and branch cankers become cracked and the overlying dead bark sloughs off.

In succeeding years dieback progresses toward the main stem(s), until most side branches are dead. At this stage epicormic sprouts, and occasionally witches' brooms, form along the trunk and towards the axils of large limbs. Trees in this advanced stage of dieback rarely recover. Ash can be salvaged for merchantable timber if harvested while the main stem is still alive (15). Dead trees are rapidly invaded by insects and by fungi that stain and decay the wood. Roots excavated from ash in advanced stages of dieback are well developed and comparable to roots of healthy trees (1).

Branch mortality occurs primarily during the dormant season, i.e., buds fail to produce new shoots in the spring. Wilted or dead foliage is not a common symptom of this disease. Dieback is gradual; tree mortality has occurred from two years after the onset of symptoms for young trees to about ten years for ash 16 inches D.B.H. and larger. Most reports (1, 19, 20) state that ash in natural sites rarely recover once afflicted with the disease. I have noted ash

in roadside and hedgerow sites in Westchester County, N.Y., where the trees were fully recovered and had no dieback in 1975. Surveys in 1960 had rated these same trees in the early stages of dieback.

Tree resistance to ash dieback is clearly evident in stands where the disease is severe. Healthy ash are scattered among dead and dying trees.

SEVERITY OF ASH DIEBACK

A survey of ash in New York in 1960-61 revealed that 37% of the trees in the sample plots were in various stages of decline, and 6% were dead (18). Another survey in 1963 (20) showed that in the six-state region of New Hampshire, Vermont, Massachusetts, Connecticut, New Jersey, and Pennsylvania, 27.2% of sampled ash were either dead or dying, and of these, 8.9% were dead. From 1965 through 1967 ash dieback remained static in New York (19). The one exception was in Dutchess County, in the southeastern section, where the disease increased in severity. From a later survey in New York in the early 1970's and from observations of ash throughout the Northeast in 1975-76 (Pers. comm. S. B. Silverborg, State Univ. N. Y., Coll. Env. Science and Forestry, Syracuse), the same stabilized condition prevails. Ash dieback, for unknown reasons, continues to increase in the Hudson Valley region, generally from Albany south to Westchester County.

PRIMARY CAUSES OF ASH DIEBACK

Research on ash dieback in New York has shown that water stress in the trees followed by invasion of the bark by canker fungi are the primary causal factors of this disease.

Drought-- Of all the etiologic agents investigated by Ross in his study of ash dieback in New York (15), periods of low rainfall constituted the only factor directly correlated with the initiation of the disease. Three extended periods of abnormally low rainfall during the growing season occurred in New York from 1950 to 1962. These droughts coincided with sudden decreases in both radial increment and shoot internodal length in ash. This association corroborates earlier observations of dieback in ash following droughts in Quebec (13) and in the Northeast (12). A recent study in New York (21) presented further evidence that the inception of ash dieback was correlated with local drought. The authors suggest that stomatal closure during periods of water stress in ash, with resulting decreases in carbon fixation, may be an additional mechanism linking drought to dieback.

Canker fungi -- The fungi Fusicoccum sp. and Cytophoma pruinosa (Fries) von Hoehnel were found to invade ash bark through wounds (14, 15). This infection causes annual cankers, which form during the dormant period between leaf fall in the autumn and leaf emergence in the spring. Canker enlargement is most rapid in early spring. The fungi are active in a canker usually only for one season. Numerous cankers on branch or stem result in death of distal portions. These canker fungi, harmless to healthy ash, act as secondary invaders whereby they attack only those trees predisposed by moisture stress. Cankers develop usually at least one growing season after the initial evidence of growth reductions caused by drought conditions.

Ross (15) concluded, "...ash dieback is induced by periods of low rainfall with the fungi acting primarily as secondary invaders which accelerate death of the tree through severe stem and branch cankering."

ADDITIONAL STRESSES ON ASH

Three observations raise the possibility that there are additional, as yet unknown, factors which should be included with the etiologic agents of ash dieback: (a) From random observations of trees in the field, dieback and mortality can occur on ash with few or no branch and stem cankers, (b) ash mortality continues in the Hudson Valley region of New York, where in recent years rainfall generally has been adequate for normal tree growth, and (c) the pattern of diseased ash within a stand sometimes suggests an infectious agent because of the outward spreading of disease from individual infection centers. Although there is no explanation for these anomalies based on research, the following disease agents should be considered in our assessment of additional stresses detrimental to ash.

Air Pollution -- Ozone is produced by the photochemical reaction of sunlight on exhaust gases from automobiles and industrial sources. It probably causes more injury to vegetation than any other pollutant in this country. Ozone has damaged vegetation in the Northeast (7, 8). Experimental fumigations have shown that white ash is one of the more sensitive deciduous trees to injury by ozone (22). It causes an upper surface purplish stippling on ash leaflets. Ozone injury may contribute to the premature fall coloration of ash foliage, which is part of the ash dieback syndrome. Ash, therefore, especially in or downwind of urban centers, is being subjected to another stress, air pollution.

Leaf Spots -- Ash is susceptible to several fungi which infect the leaves and cause necrotic lesions and scorch. Anthracnose, caused by Gloeosporium aridum Ell. and Holw.,

is especially injurious in wet springs. It causes scorching of large areas of the leaflets and premature leaf dehiscence. When environmental conditions are ideal for these foliar pathogens, they constitute an additional stress which significantly reduces the vigor of ash.

Viruses -- Viruses are infectious particles composed of a nucleic acid core within a protein coat. They multiply only within living cells. Virus particles become visible at extremely high magnification with an electron microscope. Relatively little is understood about how viruses affect forest and ornamental trees.

Two viruses have been isolated from white ash in the Northeast. A polyhedral virus was recovered from ash leaflets that had faint chlorotic spots and rings (2). These trees were located in a region of severe ash dieback in Dutchess County, New York. From the symptoms produced on a wide range of virus indicator plants, plus laboratory analyses of its physical, chemical, and serological properties, this isolate was identified (5) as tobacco ringspot virus, a known plant pathogen with a wide host range. When healthy ash seedlings were inoculated with the ringspot virus, infection sometimes resulted in significant reductions in leaf size, stem elongation, and root development (6). The dagger nematode, Xiphinema americanum Cobb, was shown to be a vector of the ash virus (4).

A rod-shaped virus was isolated from white ash in Massachusetts (9). Symptoms consisted of chlorotic rings, spots, line patterns, mosaic, and occasional reddening of the ash leaves. From similar laboratory procedures, it was identified as a strain of tobacco mosaic virus (10).

Two viruses are now known to infect white ash, but we know little about their capacity to incite or contribute to the dieback, or to predispose ash to other causal agents. We know nothing about how widespread these pathogens are over the natural range of ash. More research is required, and justified. Viruses injure trees, as we have learned from a long history of research on fruit trees. The wide herbaceous and woody host range of many viruses, the prevalence of virus vectors (insects, nematodes, pollen), and the ease of virus spread through vegetative propagation of infected plants, all increase the likelihood that viruses are infecting our forest and ornamental trees.

Mycoplasma-like organisms -- Witches' brooms have been found on the trunks of ash in advanced stages of dieback in New York (3) and Massachusetts (16). These abnormal growths consist of congested groups of twigs resulting from shortened internodes and a forcing of shoots from

axillary buds that normally remain dormant. The leaves are small, often simple rather than compound, and chlorotic. This syndrome is typical of the yellow-type dieseses, formerly thought to be caused by plant viruses.

An infectious agent was transmitted from ash with witches' brooms to healthy ash by grafting (16), and to Madagascar periwinkle (*Vinca rosea* L.) by dodder (3). The latter disease agent was identified (3) as a mycoplasma-like organism (MLO), also called a Mollicute-like organism (11). MLO's are newly discovered (in 1967) plant pathogens, heretofore associated only with animal and human diseases. The MLO's are single celled yeast-like bodies without a cell wall. They contain ribosome-like bodies and strands of DNA, and they are somewhat smaller in size than bacteria. MLO's are found primarily in the phloem sieve tubes of plants, and they are spread from plant to plant by leafhopper insects.

The importance of MLO's in the etiology of ash dieback also remains unknown until there is further research. The abundance of potential leafhopper vectors in the Northeast, and the wide host range of MLO's in herbaceous and woody plants, raise the possibility that these newly discovered plant pathogens are, or could become, widespread in ash.

CONTROL RECOMMENDATIONS

Ash with extensive dieback rarely have been seen to recover under field conditions. However, no work has been reported on attempts to encourage recovery by supplemental tree care, such as fertilization and watering. Although not based on research with ash, the following steps to increase tree vigor are recommended, both as a preventative maintenance program, and to attempt to arrest of early dieback. This program would apply to especially valuable trees in home, streetside, and park sites.

- a) Water during dry periods, especially in May, June and July.
- b) Fertilize at recommended rates for trees.
- c) Apply fungicide during wet springs to control foliar pathogens and destroy fallen diseased leaves.
- d) Apply insecticides, especially to control periodic infestations by leaf-chewing caterpillars.
- e) Prune out dead branches and cover wounds with fungicide-augmented dressing.
- f) Prevent injuries to the bark and cover wounds with fungicide-augmented dressing.

g) Prevent compacting soil in root zone; aerate soil if compacted.

h) Avoid planting white ash in sites exposed to high concentrations of air pollutants.

SUMMARY

a) Ash dieback is a disease which causes a progressive death of branches and mortality in white and green ash of all ages.

b) It was especially severe in the Northeast in the late 1950's and early 1960's, but since then ash dieback generally has stabilized. For unknown reasons, ash continue to die in southeastern New York.

c) The primary causal factors are drought followed by invasion of the bark by canker fungi.

d) Additional stresses which may be part of the etiology of ash dieback include air pollution, leaf-infecting fungi, viruses, and mycoplasma-like organisms.

e) Control recommendations are based on the maintenance of high tree vigor.

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Figure 1. Symptoms of ash dieback: (A) dead and dying white ash in hedgerow, (B) clumped leaves, (C) epicormic sprouts along main stem and thin canopy, (D) top half of tree dead.



ENDOTHIA CANKERS OF OAKS

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ABSTRACT.-- The fungal genus Endothia embraces about 14 species worldwide, most of which are pathogens or saprophytes of woody plants. Of special importance in Virginia and certain other areas in eastern United States are E. parasitica and E. gyrosa, the American chestnut (Castanea dentata) and pin oak (Quercus palustris) blight pathogens, respectively. Both canker-inciting fungi pose a potential threat to the successful culture of tree hosts which they parasitize. In addition to the near total destruction of the American chestnut and infection of Chinese chestnut (C. mollissima), E. parasitica also incites cankers on several species of oak, the most notable being the Southern live oak (Q. virginiana). Since the first documentation of the pin oak blight in 1970, this disease has been found to be more extensive and severe in eastern Virginia than was originally known. E. gyrosa attacks several other oak species, such as Q. phellos, as well as other tree genera. Disease surveys are continuing, and factors associated with disease development and control are being studied at Virginia Polytechnic Institute and State University with the hope that satisfactory disease management systems can be effected. Metro. Tree Impr. Alliance (METRIA) Proc. 1: 97-120, 1978.

THE GENUS ENDOTHIA

The genus Endothia was established by Fries (1849). It was based in part on collections made at Salem, North Carolina, in 1822 by Schweinitz who placed the fungus in the genus Sphaeria under the new epithet gyrosa. Sphaeria gyrosa then became Endothia gyrosa (Schw.) Fr., the type species of Endothia. Muller and von Arx (1962) placed the genus in the family Diaporthaceae, order Diaporthales, of the class Ascomycetes. Partial treatments of the genus are found in the works of Shear et al (1917), Muller and von Arx (1962), Kobayashi (1970) and Roane and Stipes (1976).

Mention of the genus Endothia in botanical or phytopathological circles in the United States brings to mind generally only one species, E. parasitica (Murr.) And. & And., causal agent of the earlier catastrophic blight of American chestnut (Castanea dentata (Marsh.) Borkh.) and of cankering of Chinese chestnut (Castanea mollissima Bl.) and related species (Graves, 1950; Headland *et al.*, 1976); figures 4A and 4B depict these cankers. This fungus was exotic to the North American continent until it was introduced sometime around 1900 (Shear *et al.*, 1917). It is, however, only one of five species currently found in North America. The four remaining indigenous species are E. fluens (Sow.) Shear & Stevens (= E. radicalis (Schw.) Ces. & de Not.), E. gyroosa, E. viridistroma Wehmeyer (Wehmeyer, 1936), and E. singularis (H. & P. Syd.) Shear & Stevens (Shear *et al.*, 1917). Of these taxa, only E. parasitica and E. gyroosa are considered aggressive parasites, either killing or seriously damaging certain of their hosts. A discussion of the novel aggressiveness of E. gyroosa follows in this paper.

An additional five species are found in certain tropics and subtropics on woody dicots such as Eucalyptus, Coccoloba, and Eugenia. These are E. coccolobii Vizioli (Vizioli, 1923), E. eugeniae (Nutman & Roberts) Reid & Booth (Reid and Booth, 1969), E. havanensis Bruner (Bruner, 1916), E. longirostris Earle (Earle, 1901), and E. tropicalis Shear & Stevens (Shear *et al.*, 1917). Of this group, only E. eugeniae (Nutman and Roberts, 1952) and E. havanensis (Boerboom and Maas, 1970) are aggressive parasites, especially in situations where their hosts are predisposed by unfavorable growing conditions.

The remaining four species are allegedly saprophytes. They are E. macrospora and E. japonica Kobayashi & Ito (Kobayashi and Ito, 1956), E. tetraspora Kobayashi (Kobayashi, 1965), and E. nitschkei Otth (Otth, 1868). Endothia parryi (Farlow) Cooke (Cooke, 1885) has been removed from the genus Endothia and is now designated Dothidella parryi (Farl.) Theiss. & Syd. (Theissen and Sydow, 1915). The generic status of Endothiella robiniae Chona & Munjal (Chona and Munjal, 1950), Endothia sordida Fuckel (Fuckel, 1866), and Endothiella simonianii Negru & Mozes (Negru and Mozes, 1965) is uncertain at this time. In addition, past and present morphologic, chemotaxonomic, physiologic, and numerical taxonomic studies on Endothia might provide additional insights into biological relationships as well as resolve the problem on a practical level (Emert *et al.*, 1973; Stipes and Ratcliff, 1973; Roane *et al.*, 1974; Roane and Stipes, 1974; Roane *et al.*, 1975; Stipes and Roane, 1976; Roane and Stipes, 1976).

HOSTS OF ENDOTHIA

Because the coordinators of this conference have requested that we focus our remarks on *Endothia* cankers of oaks, we have herein considered the host relations of *E. gyrosa* and *E. parasitica*, serious pathogens primarily of pin oak (*Quercus palustris* Muenchh.) and live oak (*Quercus virginiana* Mill.), respectively, in Virginia (Gruenhagen, 1965; May and Davidson, 1960; Stipes and Davis, 1972; Stipes and Phipps, 1971a). Although these disorders have been observed in certain neighboring states, they have not been reported there. In Table 1 are listed the various woody plant hosts on which *E. gyrosa* has been found. It was not possible in certain cases to determine whether the fungus was either decidedly saprophytic or parasitic; therefore, no attempt was made to make the differentiation. The pathogenic aspects of both *E. gyrosa* and *E. parasitica* will be treated in later sections of this paper.

In Table 2 are listed the various tree hosts on which *E. parasitica* has been reported. Although this pathogen decimated the natural population of *C. dentata*, several large specimens survive either by virtue of resistance or by escape; the latter thrive as disjunct populations outside the Appalachians. *E. parasitica* causes rather severe cankering of Chinese chestnut (Graves, 1950; Headland *et al.*, 1976), live oak, and less serious cankering of post oak (*Q. stellata* Wangh.) Clapper *et al.*, 1946. Ham (1967) reported that swollen butt of scarlet oak (*Q. coccinea* Muenchh.) was likely induced by *E. parasitica* (Figure 5).

ENDOTHIA GYROSA ON PIN OAK

In Virginia, pin oak is distributed naturally in the northern half of the state, but is widely planted throughout the state in both rural and metropolitan areas. We suspect that elevated temperatures coupled with drought and associated biotic factors on the southern part of its range or in landscape plantings south of its natural range, act in concert to effect what is known as "pin oak decline". In such cases, no single specific agent by itself has ever been deemed able to cause decline and death. Hepting (1971) has annotated biotic and abiotic disease agents of pin oak.

In 1970, the senior author was summoned by Virginia Tech Extension personnel to the Tidewater Virginia area to diagnose a purportedly new and widespread decline and death of pin oak. After careful notation of many case histories and observations of numerous trees, a species of Endothia was consistently noted with the dying of individual branches and in some cases entire trees (Stipes and Phipps, 1971a). Stipes *et al* (1971) confirmed the species as E. gyrosa. Although the syndrome varied, a dieback was consistently observed (Figures 2B and 2C). Premature chlorophyll degradation(fall coloration) and some leaf abscission were seen. Leaves on infected branches exhibited a deep marginal scorch, and in advanced stages of the disease they became entirely brown. This toxin-like necrosis of leaves together with the observation of staining of sapwood beneath infected bark (Weir, 1925) suggested to us the possible elaboration of toxin(s) by E. gyrosa. This, then, would extend the causation of the syndrome beyond that of simple preclusion of photosynthate movement by a necrotic phloem.

Cankers were observed fairly consistently on branches from which smaller adjoining ones had been pruned. Lesions were discrete, sunken and elongate, bordered commonly by a calloused fold. Because of the perennial nature of the canker, concentric calluses were often but not always seen.

Upon initial observation, fruiting bodies were reminiscent of those of E. parasitica, but they were decidedly larger (Figure 2D). Although not seen on all infected tissues, these pulvinate stromata, predominantly solitary, were usually abundant in most cases on canker surfaces. They were yellow to bright orange at early development, then exhibited a dark cinnamon-brown appearance upon maturation. Tree boles of blighted trees at Lynchburg and Alexandria were sometimes covered with stromata. The stromal surface was sometimes papillose and in cryostat cross-sections of stromata there were labyrinth-form pycnidial cavities with bacillloid conidia. Perithecia, present only in the lower strata of the more mature stromata, yielded allantoid one-celled ascospores; thereby the pin oak pathogen was differentiated from E. parasitica which has fusoid, two-celled ascospores.

Table 1. Woody plant hosts of Endothia gyrosa as recorded in various reports, without specification as to parasitic or saprophytic habit.^a

<u>Acer saccharinum</u> Mill.	<u>Q. lyrata</u> Walt.
<u>Castanea dentata</u> (Marsh.)Borkh.	<u>Q. macrocarpa</u> Michx.
<u>Fagus grandifolia</u> Ehrh.	<u>Q. marilandica</u> Muenchh.
<u>Fagus sylvatica</u> L.	<u>Q. montana</u> Willd.
<u>Ilex opaca</u> Ait.	<u>Q. nigra</u> L.
<u>Liquidambar formosana</u> Hance	<u>Q. palustris</u> Muenchh.
<u>Liquidambar styraciflua</u> L.	<u>Q. phellos</u> L.
<u>Quercus agrifolia</u> Nee	<u>Q. prinus</u> L.
<u>Q. alba</u> L.	<u>Q. rubra</u> L.
<u>Q. bicolor</u> Willd.	<u>Q. sempervirens</u> (live oak)
<u>Q. borealis</u> Michx. f.	<u>Q. stellata</u> Wangh.
<u>Q. coccinea</u> Muenchh.	<u>Q. suber</u> L.
<u>Q. digitata</u> (Marsh.)Sudw.	<u>Q. velutina</u> Lam.
<u>Q. falcata</u> Michx.	<u>Q. virens</u> (live oak)
<u>Q. georgiana</u> Curtis	<u>Q. virginiana</u> Mill.
<u>Q. ilicifolia</u> Wangh.	<u>Ulmus americana</u> L.
<u>Q. imbricaria</u> Michx.	<u>Vitis</u> sp.

^a

Annotated from Hepting(1971), Miller(1940), New York Botanical Gardens Herbarium, Roane et al (1974), Shear et al (1917), Snow et al (1974), Stevens (1917), R. J. Stipes & M. K. Roane (personal collections), USDA Agr. Handbook 165 (1960), U. S. Mycological Collections,USDA, Beltsville, Md., and Van Arsdel (1972).

As mentioned previously, E. gyrosa has been found associated with cankers or with moribund tissues of several other species of oak as well as other tree genera. In many of these reports, it cannot be determined whether this fungus was an aggressive parasite on either a stressed or non-stressed host or simply a secondary colonizer of tissues dying from other (primary) causes. Past reports have depicted E. gyrosa as an indigenous, biologically balanced, non-aggressive parasite. For example, Weir (1925), who inoculated roots of Q. velutina and Fagus americana Sweet (=F. grandifolia Ehrh.) with E. gyrosa, stated that "this fungus in artificially inoculated roots is able to gradually increase the infected area through the activities of its own mycelium, resulting in the death of the root or that part of it above ground" and that this "indicates the slow parasitism of this fungus. It enters entirely through wounds and will sometimes continue indefinitely producing its stromata on a very small infected area. This indicates the inability of the fungus to become parasitic during the early stages of growth." The USDA Agriculture Handbook No. 165, Index of Plant Diseases in the United States (Anon., 1960) further reports that E. gyrosa occurred on Q. palustris only on exposed roots and dead branches, a decidedly saprophytic or weakly parasitic habit. Shear *et al* (1917) stated that "none of these (Endothia) species except Endothia parasitica has thus far been found to be actively parasitic." Stevens (1917) observed that E. gyrosa had "a much wider known range in America than any other species of the genus. This fungus is undoubtedly indigenous, having first been collected by Schweinitz at Salem, North Carolina, nearly a century ago, and previous to recent work had been collected at various times in the following widely separated localities: Indiana, 1831(?), Schweinitz; Texas, 1869, Ravenel; New York, 1872, G. W. Clinton; Florida, 1886-87, Calkins; Mississippi, 1887, Earle; Kansas, 1887, Swingle; Louisiana, 1887, Langlois; New Jersey, 1892(?), Ellis." Figure 1B illustrates the distribution of E. gyrosa in the United States by 1917 (Shear *et al*, 1917).

In contrast to these reports, Stipes and Phipps (1971) observed a distinctly new blighting on pin oak that must be considered a novel pathological situation associated with this fungus because of its severity, extensity, and consistency. Major infection centers now include the Tidewater Virginia complex and contiguous counties, the Eastern Shore of Virginia, and Lynchburg, with sites of lesser frequencies and intensities in the Virginia Piedmont and the Virginia section adjacent to Washington, D. C.

In view of the information currently extant, we have suggested three possibilities that might explain this new blighting situation: (1) A new exotic strain might have been introduced since the most extensive disease situation occurs at Hampton and in the general Tidewater complex (Norfolk, Newport News, Portsmouth, Hampton, Virginia Beach), major shipping and receiving areas along the Atlantic Seaboard, (2) Pin oak, herein growing at the southernmost boundary of its natural range and under periodic moisture-stressed situations as monitored by precipitation records, may be predisposed to infection and severe blighting by a traditionally weak parasite, or (3) A new pathogenic strain of the indigenous E. gyrosa may have been generated via heterocaryosis, mutation, parosexuality or by sexual recombination.

Environmental stresses, i.e., extremes in moisture, temperature, nutrient availability, etc., have been implicated commonly as predisposing factors to infection by parasites (Schoenweiss, 1975). In such cases, virulent pathogens become even more aggressive and weak parasites become notably aggressive. Because pin oak is allegedly a wet-site species, it would appear that moisture stress might be a predisposing factor to infection by E. gyrosa. Although there is no documentation with sophisticated instrumentation, one is impressed by the vigor of many large pin oaks which certainly must endure not only moisture stress and nutrient deficiencies but elevated temperatures and crowded conditions because of pavement (highway, driveway, sidewalk) construction over root zones (Figure 2A). Pavements prevent the interception of rain, and soil compaction often occurs in the area that is not paved. In a preliminary study, Stipes (unpublished data) found that greenhouse seedlings soil-moisture stressed to near permanent wilting percentage and then artificially inoculated on decapitated laterals were markedly more susceptible to incursion and blighting by the pathogen than those inoculated similarly but maintained near field capacity. Hunter (1977) found a relationship between drying of pruned branch stubs of pin oak and the development of E. gyrosa in them. Investigations of a possible relationship between changes in carbohydrate and free amino acid fractions with stub drying and pathogen nutrition failed to support such a relationship. It was suggested that some other mechanism was implicated. Therefore, total research to date has not revealed the basis for the epiphytotic blighting of pin oak by E. gyrosa.

Entry of most, if not all, fungal canker pathogens of trees is made through natural, environmentally induced or man-made wounds. Numerous wounds are probably the rule and not the exception in the majority of landscape trees or all trees in general; these are caused by birds, squirrels and other rodents, insects, wind, hail, alternate freezing and thawing, natural pruning and man's activities. In the case of pin oak blight, there is a direct and nearly consistent association of infection of decapitated lateral branches commonly found on the home or municipal landscape. These branches are pruned off not only by homeowners to avoid being gouged by the sharp terminals but also by utility companies and municipal work crews. Sanitation techniques are rarely, if ever, applied.

These wounds, then, serve as infection courts for E. gyrosa and should be avoided. Wounds other than man-made ones apparently allow entry and colonization by E. gyrosa of branches in diseased trees that have not been pruned.

Although the most effective disease control measures must be predicated upon a clear definition of causal factors, we believe that infection can be curtailed to varying degrees by providing supplemental watering during dry periods, avoiding the pruning of laterals, and culturing of pin oak in areas as devoid as possible of pavement construction and soil compaction.

ENDOTHIA PARASITICA ON LIVE OAK

Live oaks as a group are constituted of different species depending upon the section of the country to which one refers (Hepting, 1971). Hence, the necessity of Latin binomials in conjunction with colloquial names becomes obvious. As a group they are evergreen, have very dense wood, grow to large diameters, and although they are now used rather exclusively in landscapes, were used in times past in ship-building. The group is represented by (1) Quercus agrifolia Nee, California live oak or coast live oak of the Far West, (2) Q. chrysolepis Liebm., canyon live oak of the West and Mexico, and (3) Q. virginiana, the subject of this section of the paper.

Quercus virginiana, variously known as live oak, Eastern live oak, Virginia live oak, scrub live oak, dwarf live oak and Rolfs oak, has a fairly restricted range, extending in a narrow coastal strip from Virginia to Georgia where the range widens to embrace the southern third of Georgia and all of Florida to Key Largo. It again becomes a coastal strip tree from western Florida to Texas, where

Table 2. Tree hosts of *Endothia parasitica*, as recorded in various reports, with specifications neither to parasitic nor saprophytic habit.^a

<u>Acer palmatum</u> Thunb.	<u>Q. montana</u> Willd.
<u>Acer pensylvanicum</u> L.	<u>Q. muhlenbergi</u> Engelm.
<u>Acer rubrum</u> L.	<u>Q. petraea</u> (Matt.) Lieb.
<u>Carpinus caroliniana</u> Walt.	<u>Q. prinus</u> L.
<u>Carya ovata</u> (Mill.) K.Koch	<u>Q. pubescens</u> Willd.
<u>Fagus sylvatica</u> L.	<u>Q. robur</u> Mill.
<u>Liriodendron tulipifera</u> L.	<u>Q. rubra</u> L.
<u>Ostrya virginiana</u> (Mill.) K.Koch	<u>Q. sessiliflora</u> Salisb.
<u>Quercus alba</u> L.	<u>Q. stellata</u> Wangh.
<u>Q. coccinea</u> Muenchh.	<u>Q. velutina</u> Lam.
<u>Q. falcata</u> Michx.	<u>Q. virginiana</u> Mill.
<u>Q. ilex</u> L.	<u>Rhus typhina</u> L.
<u>Q. macrocarpa</u> Michx.	

^a

Annotated from Anderson and Rankin (1914), Bazzigher (1953), Biraghi (1950), Clapper et al (1946), Clinton (1913), Darpoux (1948), Darpoux (1949), Fulton (1912), Gravatt (1949), Gravatt(1952), Ham (1967), Heald(1943), May and Davidson (1960), Seymour (1929), Shear et al(1917).

List does not include Castanea and Castanopsis.

its range widens, extending about 483 km (300 mi) inland (Fowells, 1965). Little (1944) listed several varieties: macrophylla, virescens, typica, eximea, fusiformis, and geminata.

Although live oak is sensitive to low temperatures which thereby presumably restrict its range, a nice specimen thrives in the Appalachians at Blacksburg, Virginia (altitude about 640m = 2,100 ft). Several large specimens thrive also at Richmond, Virginia. Many large and old specimens adorn landscapes in the Tidewater area of Virginia, especially at Hampton Institute and at the U.S. Army Compound, Fort Monroe, both at Hampton, Virginia. This species apparently has been relatively resistant to disease and insect attack until the introduction of the chestnut blight organism around 1900, after which time several species of oak, including live oak, contracted the disease.

As early as 1933 and 1934, Taubenhaus described a decline of live oak near Austin, Texas, that killed more than 200 trees. The possibility of drought injury was excluded and evidence for natural spread was indicated even though the cause was not determined (Taubenhaus, 1933 and 1934; Halliwell, 1964). Dunlap and Harrison (1949) also studied the declining trees over an 8-year period and found that environment had little effect on the disease. The disorder was seen in both landscape and forest sites, on acid and alkaline soils, in sand and heavy clay soils, and in wet as well as in dry soils. Clinical examinations yielded no clues.

The syndrome as described by Halliwell (1966), which required 3 to 8 years from initiation to death, included (1) a marginal necrosis of leaves that proceeded inward, (2) defoliation on individual branches rather than the entire tree, (3) twig dieback and suckering of the main branch, and (4) discoloration and acetic acid odor in the heartwood and vascular system. He consistently isolated a Cephalosporium sp. from discolored heartwood and vascular tissue of not only naturally infected live oak but also water oak, Southern red oak, and post oak. Using various inocula and inoculation techniques, Halliwell reproduced the syndrome in live oak and, after fulfilling Koch's Postulates by re-isolating the Cephalosporium, suggested that the disease be designated as "Cephalosporium decline of oak". In a sequel to this work, Van Arsdel and Halliwell (1970) emphasized that live oak decline involved a causal complex of Cephalosporium sp. (= Phialophora obscura), Dothiorella quercina, Hypoxyylon atropunctatum, and possibly mechanical root disturbance.

In a still later paper, Van Arsdel (1972) indicated that the Cephalosporium sp. in question was "probably C. diospyri Crandall although other spore stages in the life cycle suggest that this name will be superseded."

In contrast to these reports from Texas, the live oak decline situation in Virginia and other states along the Atlantic Seaboard and Gulf Coast east of Texas involves a somewhat different syndrome and entirely different associated fungus. Dieback, defoliation, and stagheading (Figure 4A) are seen in addition to loosening, cracking, and exfoliation of bark (Figures 4B,4C), revealing mycelial fans of the associated fungus (Figure 4D). May and Davidson (1960) identified Endothia parasitica fruiting bodies on bark and E. parasitica buff-colored mycelial fans in and under the bark of cankered areas on Quercus virginiana from Colonial Williamsburg. Although they had not reproduced the disease in live oak, American chestnut trees inoculated with their isolate from live oak developed typical E. parasitica - induced chestnut blight cankers. Inoculated greenhouse cork oak (Quercus suber L.) seedlings also developed cankers having vertical fissures (Figure 3C). Gruenhagen (1965) examined live oak specimens from declining trees in the Fort Monroe and Newport News areas of Virginia. Although he found no cankers, biopsies from the Fort Monroe specimen yielded a fungus similar to that reported by May and Davidson(1960). Endothia parasitica cankers on live oak were reported later in Virginia (Stipes and Phipps, 1971b; Stipes and Davis, 1972). Batson and Witcher (1968) proved pathogenicity of E. parasitica on artificially inoculated landscape live oaks at Georgetown, South Carolina. Peacher (1969) reported E. parasitica cankers on live oak in Mississippi, and Phelps (1974) reported it for the first time from North Carolina and Florida. Unpublished reports have indicated that E. parasitica canker of live oak occurs in Alabama and possibly in other states or areas where live oak grows (Anon., 1964).

In Virginia, it is difficult to find a non-cankered live oak. Although older and larger trees are more heavily cankered than younger ones, those with a diameter of 15.2 cm (6 in) or so can be cankered. Stromata are found commonly on moribund tissues of blighted trees, although they are not produced consistently on calloused folds of all canker lesions (Stipes, unpublished). The mode of transmission has not been determined, but it is presumed that the same agents that were documented to transmit E. parasitica from lesions on American chestnut trees also may be involved in its transmission in the case of live

oak canker. Pruning tools also would be suspect when used first on diseased and then on healthy trees. Because of the relatively large number of hosts and therefore abundance of inoculum of E. parasitica, precautions should be taken to avoid unnecessary wounds that could serve as infection courts. Figure 5E depicts a healed wound on Q. virginiana from which a canker had been excised. Stipes (Unpublished data) was able to isolate E. parasitica from such calluses on live oak at Colonial Williamsburg (Stipes and Phipps, 1971b).

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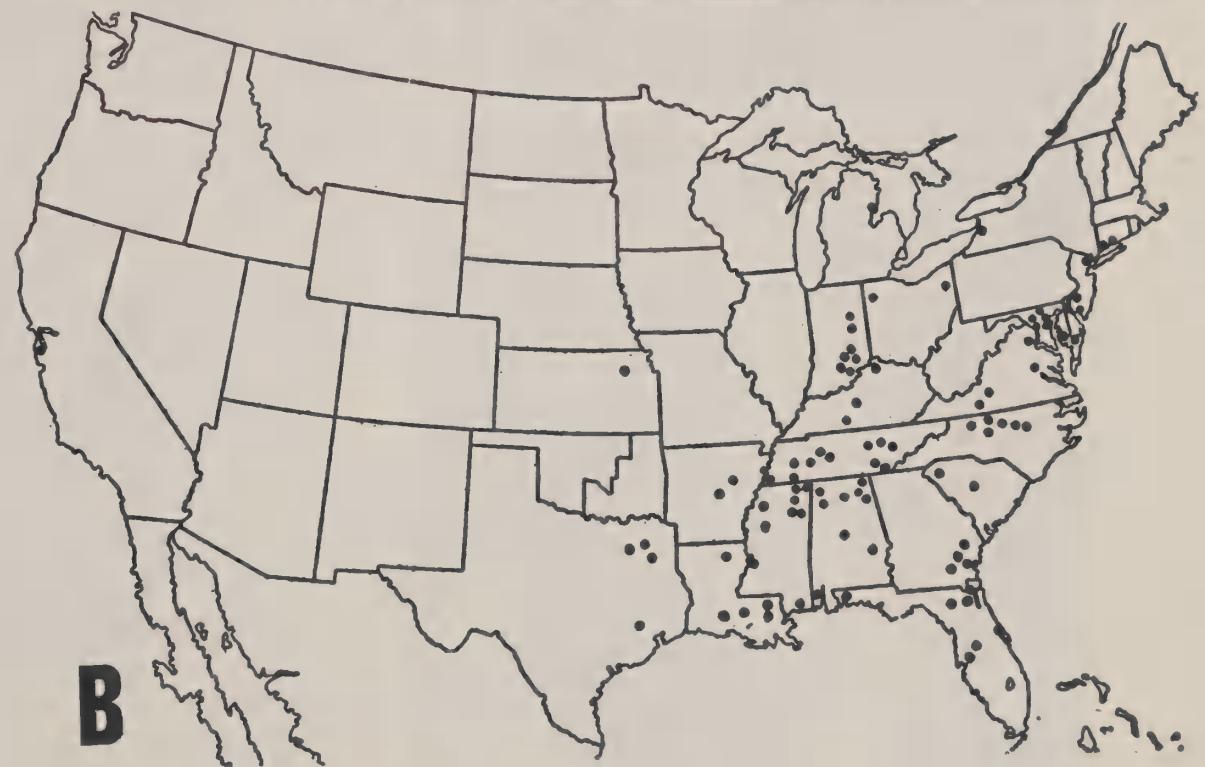
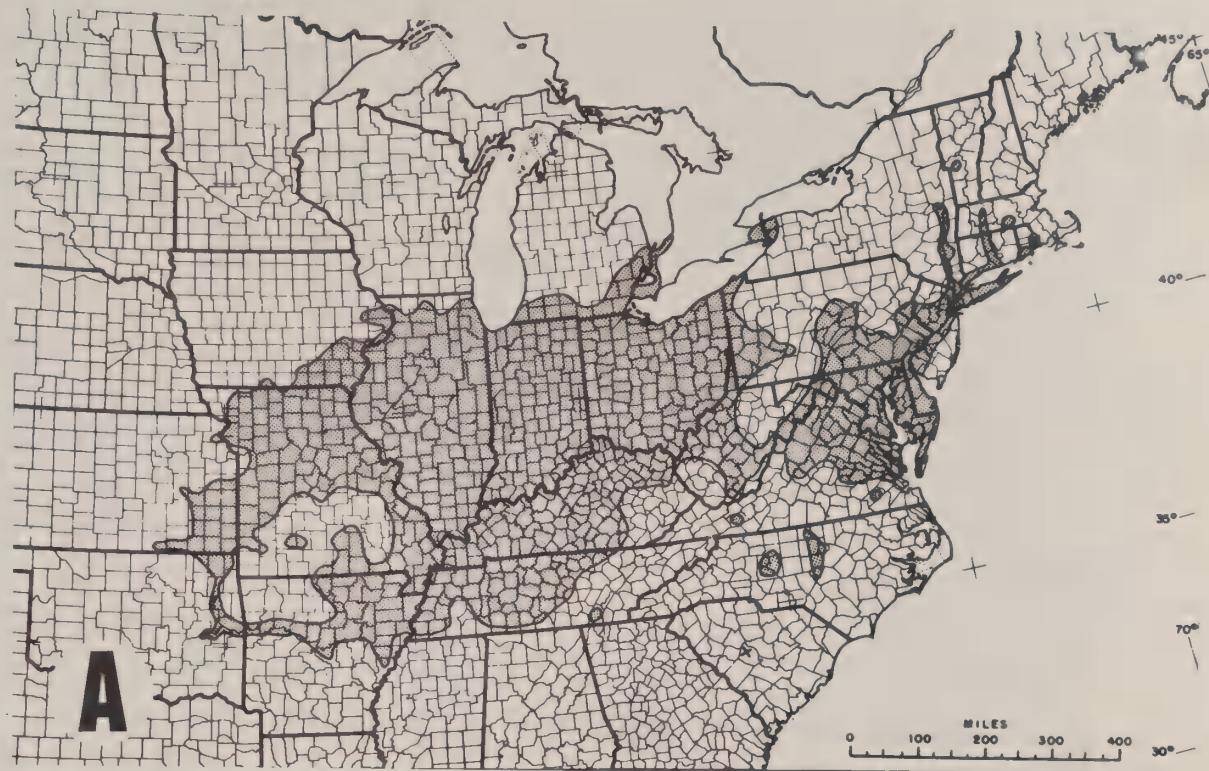


Figure 1. Distribution of (A) pin oak, *Quercus palustris* (Fowells, 1965) and (B) *Endothia gyroza*, the pin oak blight fungus (Shear et al., 1917) in the United States.

Figure 2. Pin oak blight. A. Typical crowded growing space, due to sidewalk, driveway and road construction (and expansion), commonly available to pin oak. B. Dieback, stagheading and defoliation syndrome. C. Re-sprouting of blighted pin oak that had been pruned to surgically remove diseased tissue. D. Endothia gyrosa canker. Note that the fungus gained entrance through the pruned secondary branch.

Figure 3. Cankers caused by Endothia parasitica. A. American chestnut (Castanea dentata), natural infection. B. Chinese chestnut (Castanea mollissima), natural infection (Photo courtesy of Dr. G. J. Griffin in Headland et al(1976). C. Cork oak, Quercus suber, that was artificially inoculated by Dr. Curtis May with isolate obtained from live oak (Q. virginiana) canker at Colonial Williamsburg, Virginia (May and Davidson, 1960).

Figure 4. Endothia parasitica canker and blight of live oak (Quercus virginiana). A. Dieback and defoliation of tree at Colonial Williamsburg, Virginia. B. Usual initial visible symptom is loosening and cracking of bark. C. Bark is easily removed by hand. D. Exposed wood revealing typical mycelial fans. Cankers are bordered by callused "lip". E. A large callused border has developed following surgical removal of canker (Williamsburg).

FIGURE 2



FIGURE 3

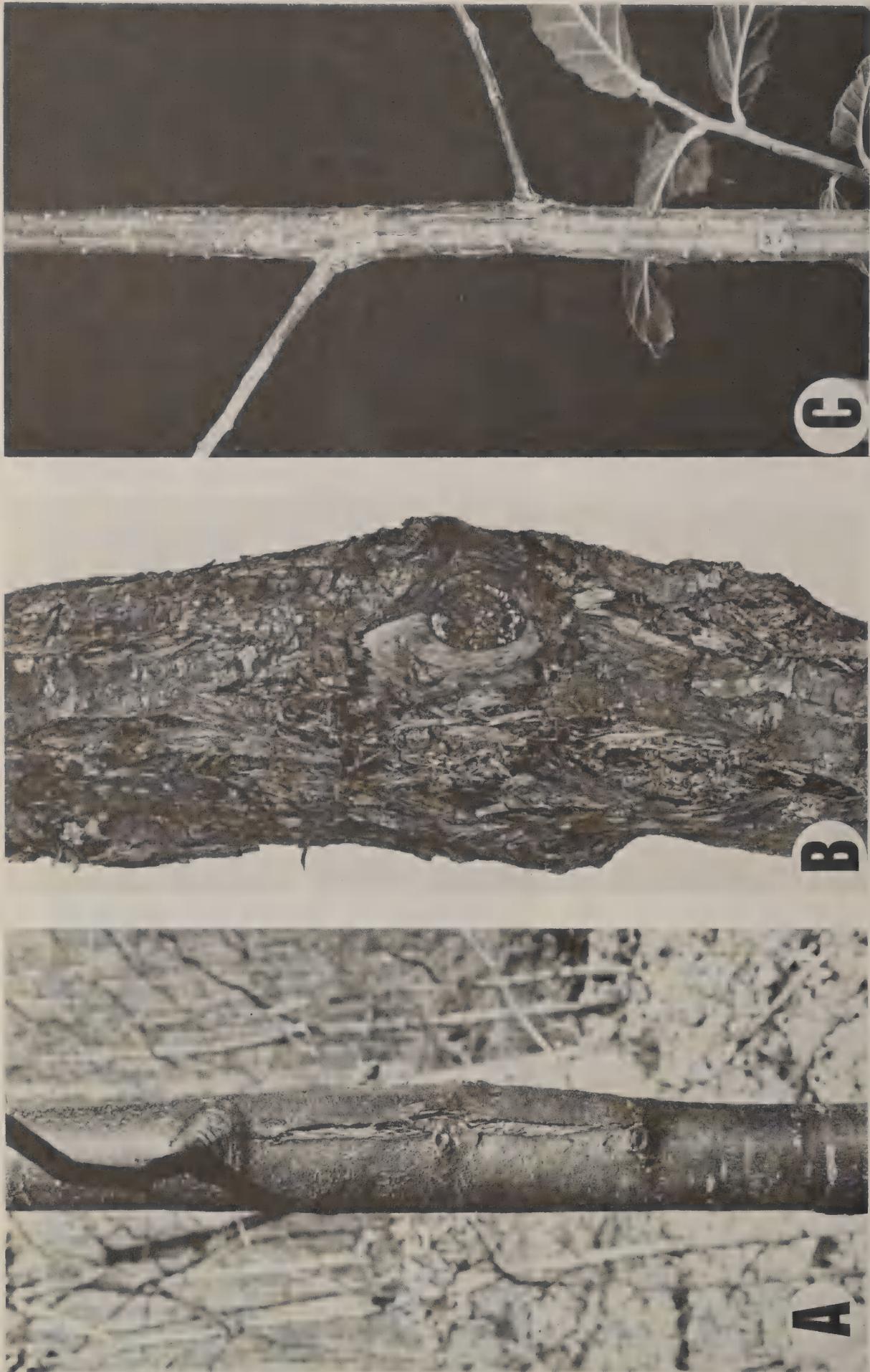


FIGURE 4

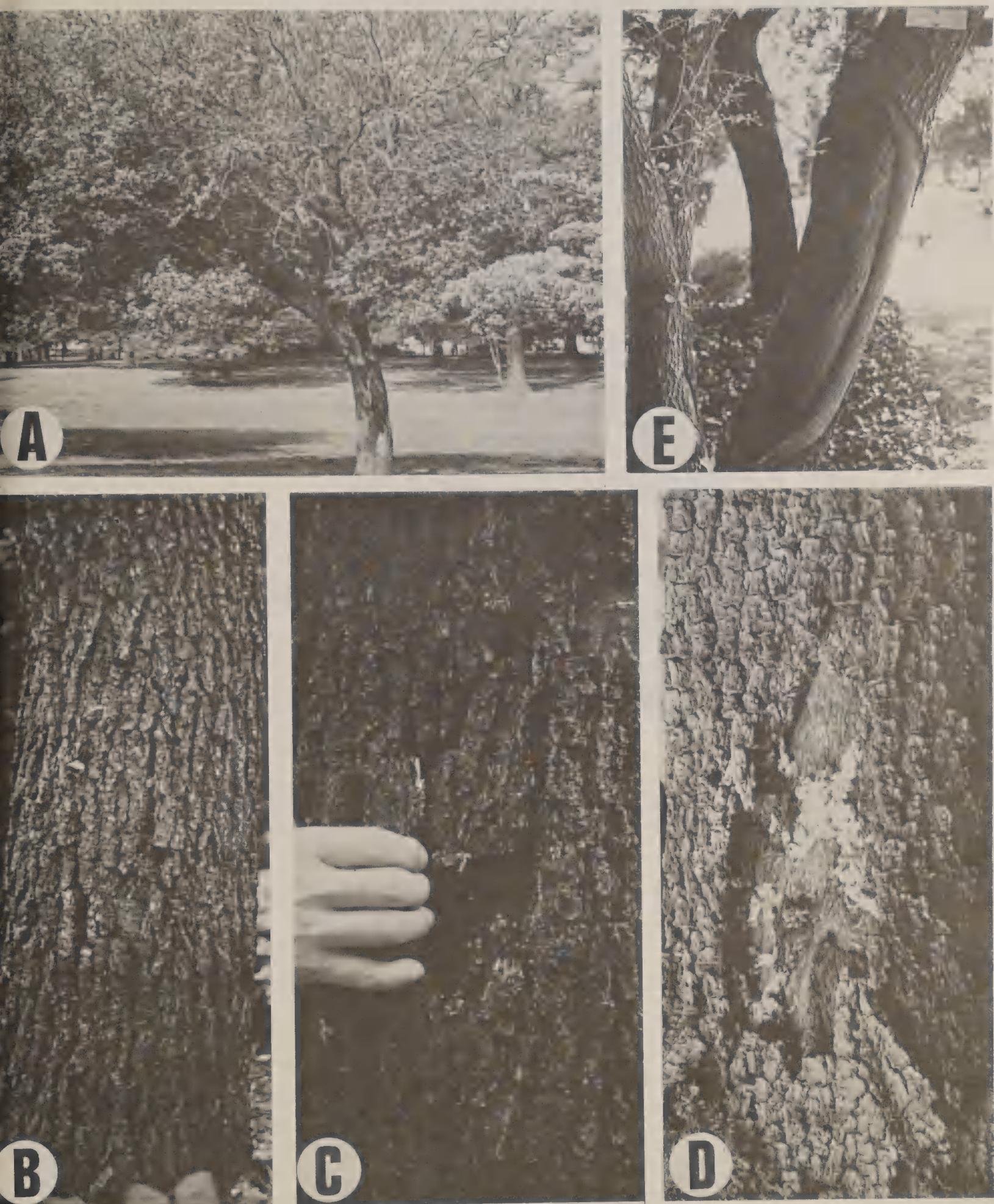




Figure 5. Swollen butt of scarlet oak (Quercus coccinea) resulting from infection by Endothia parasitica. Photo courtesy of Dr. D.L. Ham (Ham, 1967).

ELECTION OF OFFICERS

The Nominating Committee, chaired by Silas Little, in accordance with the Constitution, presented a slate of candidates for consideration by the membership. The slate was accepted and the make-up of the Executive Council is as follows:

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